Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals During a Marine Seismic Program off the Northern Yucatán Peninsula, Gulf of Mexico, March–April 2004

submitted by

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to

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SUMMARY

Lamont-Doherty Earth Observatory (LDEO), a part of Columbia University, requests—pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5)—that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to a planned seismic survey off the northern Yucatán Peninsula, in the Gulf of Mexico. The survey will be conducted in an area between 21º and 22.5ºN and between 88º and 91ºW (Fig. 1). The operations will take place in the Exclusive Economic Zone (EEZ) of Mexico. LDEO has requested State Department clearance to conduct the seismic survey in the Mexican EEZ.

The National Science Foundation (NSF) is the agency of the U.S. Government that is providing the funds to support the research to be undertaken on this research cruise. NSF's view is that the Marine Mammal Protection Act does not apply to activities undertaken in the EEZ of a foreign nation. The submission of this IHA application to the National Marine Fisheries Service by LDEO does not constitute a waiver of NSF's position.

As presently scheduled, the seismic survey will take place for ~31 days during March and April 2004, probably commencing in early March. However, the exact dates may vary as project plans become more precise.

LDEO requests that it be issued an IHA authorizing incidental, non-lethal takes of marine mammals in the course of this seismic program. The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests" are set forth below. This includes descriptions of the specific operations to be conducted, the marine mammals occurring in the study area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on these marine mammals. No measures will be necessary to minimize conflicts between the proposed operation and subsistence hunting, because legal hunting for marine mammals does not occur within the immediate area of the proposed activity.

The purpose of the seismic survey is to study the Chicxulub Crater. The Chicxulub Crater was formed sixty-five million years ago when a massive meteor crashed into the Yucatán Peninsula of Mexico leaving behind the crater with a diameter of about 150 km (93 mi.). The well-known massive extinction event at the Cretaceous-Tertiary (K-T) boundary appears to have been caused, at least in part, by this impact. It is also the only large terrestrial impact crater with a well preserved topographic peak ring. The Chicxulub Crater is uniquely suited for a seismic investigation into the deformation mechanisms of large diameter impacts in general and the physical parameters of the K-T impact in particular.

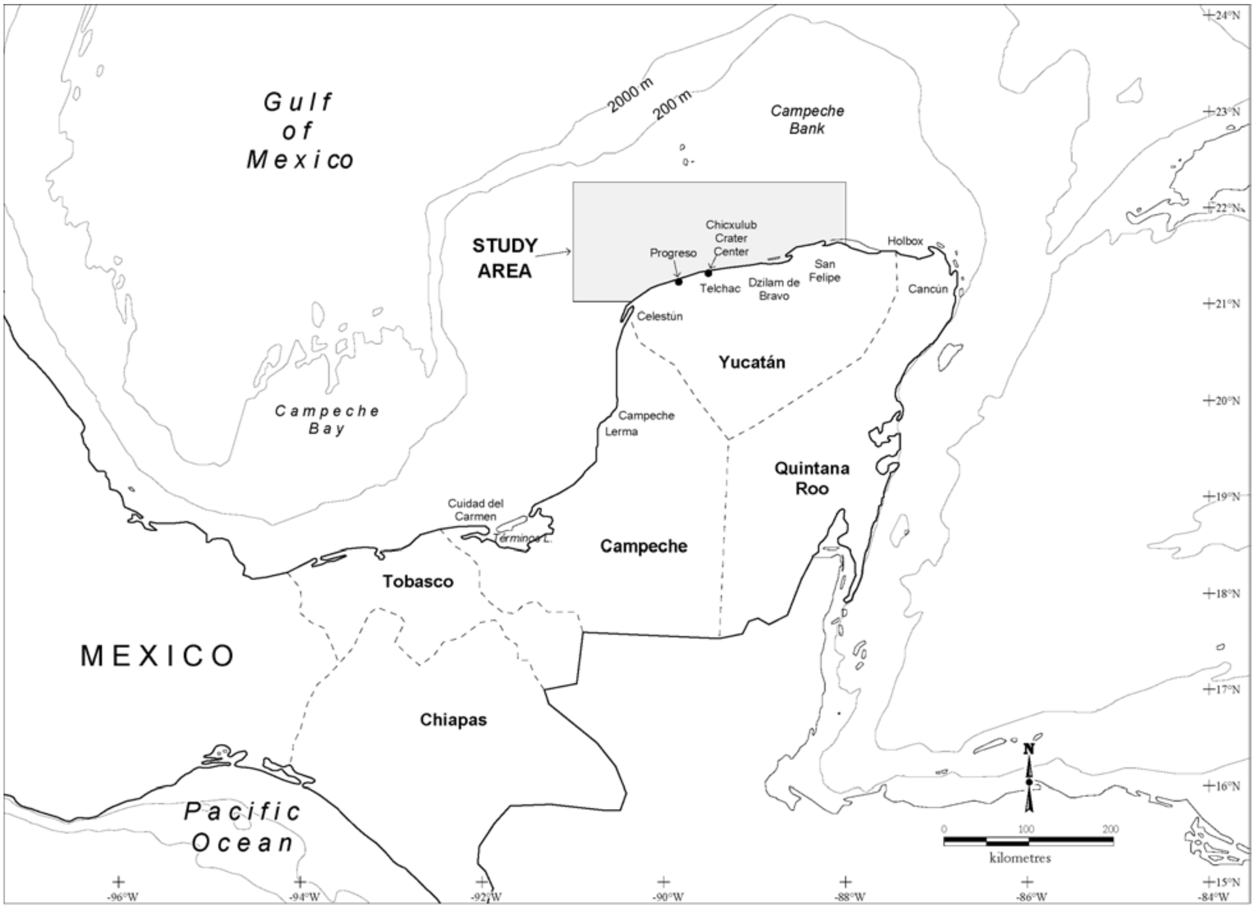

FIGURE 1. The study area north of the Yucatán Peninsula in the Gulf of Mexico.

Numerous cetaceans, including some species listed under the U.S. Endangered Species Act (ESA), are present in the study area. In addition, West Indian manatees as well as vagrant pinnipeds could occur in the study area, although it is unlikely that any will be encountered. LDEO is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

I. Operations to be Conducted

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

Lamont-Doherty Earth Observatory (LDEO), on behalf of the National Science Foundation (NSF), plans to conduct a seismic survey off the northern Yucatán Peninsula, in the Gulf of Mexico. The cruise is scheduled to occur from March to April 2004.

The purpose of the seismic survey is to study the Chicxulub Crater. The Chicxulub Crater was formed sixty-five million years ago when a massive meteor crashed into the Yucatán Peninsula of Mexico leaving behind the crater with a diameter of about 150 km (93 mi.). The well-known massive extinction event at the Cretaceous-Tertiary (K-T) boundary appears to have been caused, at least in part, by this impact. In addition to being the "smoking gun" for the K-T extinction event, Chicxulub is well preserved due to a cover of ~1 km (3280 ft) of Tertiary carbonates. It is also the only large terrestrial impact crater with a well preserved topographic peak ring. The Chicxulub Crater is uniquely suited for a seismic investigation into the deformation mechanisms of large diameter impacts in general and the physical parameters of the K-T impact in particular. The goals are fourfold:

1. To determine the direction of approach and angle of the Chicxulub impact through the collaborative seismic and modeling effort. Experimental and numerical modeling studies show that vaporization depends on impact angle, with oblique impacts resulting in as much as a 15–20 fold increase in vapor production. Thus, any data that are obtained on the obliquity of the Chicxulub impact will help quantify the amount of volatiles released into the atmosphere by the K-T event.

2. Map the deformation recorded in the upper crust near the crater center that may yield important information about the kinematics of large bolide impacts.

3. Image the peak ring and other morphologic features in the northwest quadrant of the crater to further understand the physical parameters of the Chicxulub impact structure.

4. Model the 3D collapse of an asymmetric transient crater. This modeling will not only better understand the mechanics of large impact craters, but will also quantify many of the environmental effects of the KT impact.

The high-resolution seismic survey will involve one vessel, the R/V *Maurice Ewing*. The *Ewing* will deploy a 20-airgun array as an energy source, Ocean Bottom Seismometers (OBSs), plus a towed hydrophone streamer, varying in length from 3 to 6 km (1.6–3.2 n.mi.) As the airgun array is towed along the survey line, the towed hydrophone streamer or OBSs will receive the returning acoustic signals .

The program will consist of approximately 3313 km (1789 n.mi.) of surveys. Water depth in the area is <100 m (<328 ft), and almost all of the survey (*c.* 99%) will be conducted in depths <50 m (<164 ft). There will be additional operations associated with equipment testing, startup, line changes, and repeat coverage of any areas where initial data quality is sub-standard.

All planned geophysical data acquisition activities will be conducted by LDEO with on-board assistance by the scientists who have proposed the study. The scientists are headed by Dr. Penny Barton of the University of Cambridge, U.K., and Dr. Sean Gulick of the University of Texas Institute for Geophysics, Austin, TX. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Procedures to be used for the 2004 seismic survey will be similar to those during previous seismic surveys by LDEO, e.g., in the equatorial Pacific Ocean (Carbotte et al. 1998, 2000). The proposed program will use conventional seismic methodology with a towed airgun array as the energy source, and a towed hydrophone streamer and/or ocean bottom seismometers (OBSs) as the receiver system. The energy to the airgun array will be compressed air supplied by compressors on board the source vessel.

In addition to the airgun array, a multibeam bathymetric sonar will be operated from the source vessel continuously throughout the entire cruise, and a lower-energy sub-bottom profiler will also be operated during most of the survey.

Vessel Specifications

The vessel R/V *Maurice Ewing* will be used as the source vessel. It will deploy the airgun array and OBSs, and it will tow a streamer containing hydrophones along predetermined lines. The *Ewing* has a length of 70 m (230 ft), a beam of 14.1 m (46.3 ft), and a draft of 4.4 m (14.4 ft). The *Ewing* has four 1000 kW diesel generators that supply power to the ship. The ship is powered by four 800 hp electric motors that, in combination, drive a single 5-blade propeller in a Kort nozzle and a single-tunnel electric bow thruster rated at 500 hp. At the typical operation speed of 7.4–9.3 km/h (4–5 knots) during seismic acquisition, the shaft rotation speed is about 90 rpm. When not towing seismic survey gear, the *Ewing* cruises at 18.5–20.4 km/h (10–11 knots) and has a maximum speed of 25 km/h (13.5 knots). It has a normal operating range of about 31,500 km (17,000 n.mi.).

The *Ewing* will also serve as the platform from which vessel-based marine mammal observers will watch for marine mammals before and during airgun operations. The characteristics of the *Ewing* that make it suitable for visual monitoring are described in § XI, MITIGATION MEASURES.

Other details of the *Ewing* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1983 (modified in 1990)
Gross Tonnage:	1978
Fathometers:	3.5 and 12 kHz hull mounted transducers; Furuno FGG80 Echosounder; Furuno FCU66 Echosounder Recorder
Bottom Mapping Equipment:	Atlas Hydrosweep DS-2, 15.5 kHz (details below)
Compressors for Air Guns:	LMF DC, capable of 1000 scfm at 2000 psi
Accommodation Capacity:	21 crew plus 3 technicians and 26 scientists

Airgun Description

During the Chicxulub Crater survey, an array consisting of 20 Bolt airguns will be used. Seismic pulses will be emitted at intervals of ~20 seconds. The 20-s spacing corresponds to a shot interval of about 50 m (164 ft). The 20-gun array will consist of airguns ranging in chamber volume from 80 to 850 in^3, with a total volume of 8575 in^3 (Fig. 2). The 20 guns will be spaced across an approximate area of 35 m or 115 ft (across track) by 9 m or 30 ft (along track).

Because the source is a distributed sound source (20 guns) rather than a single point source, the highest sound level measurable at any location in the water will be less than the nominal source level (Caldwell and Dragoset 2000). Also, because of the directional nature of the sound from the airgun array, the effective source level for sound propagating in near-horizontal directions will be substantially lower.

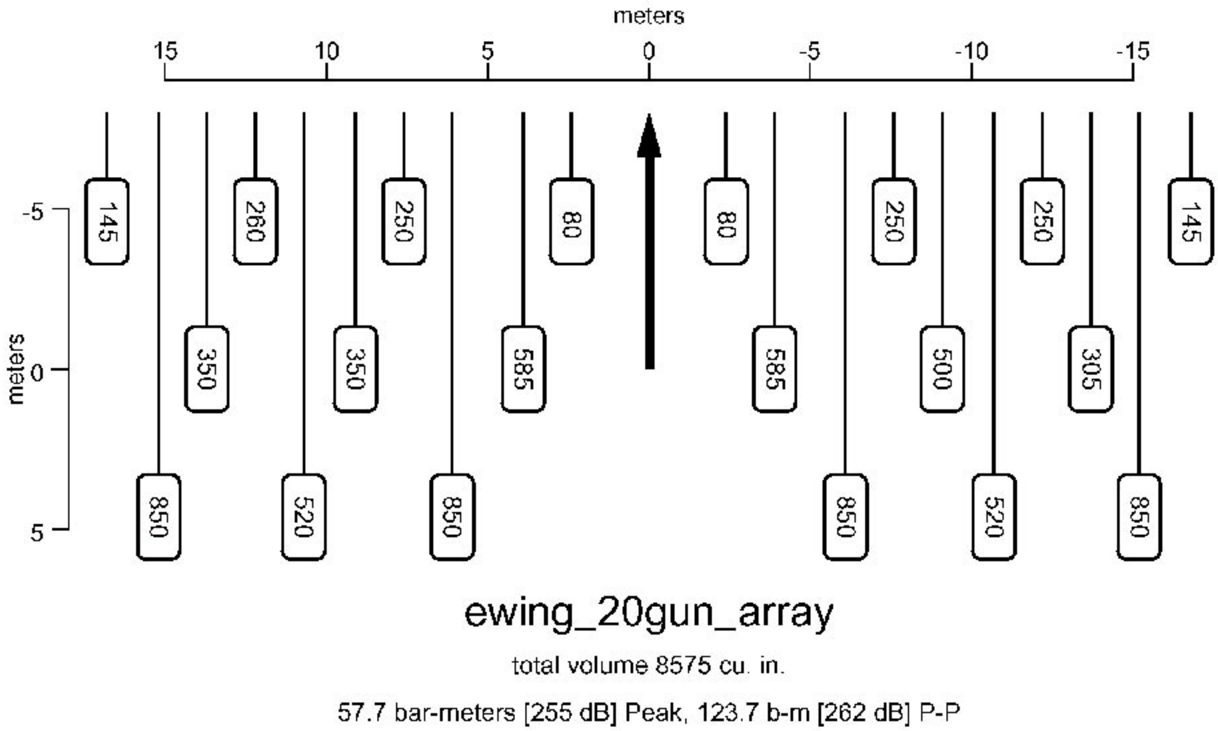

FIGURE 2. Configuration of the 20-gun array that will be used during the survey off the northern Yucatán Peninsula in the Gulf of Mexico, March–April 2004.

20-Airgun Array Specifications

Energy Source	Twenty 2000 psi Bolt airguns of 80–850 in^3
Source output (downward)[1]	0-pk is 58 bar-m (255 dB re 1 µPa·m); pk-pk is 124 bar-m (262 dB)
Towing depth of energy source	7.0 m
Air discharge volume	~8575 in^3
Dominant frequency components	0-188 HzGun positions used see Fig. 2
Gun volumes at each position	see Fig. 2

The sound pressure field for the 20-gun array has been modeled by LDEO, in relation to distance and direction from the airguns, and is depicted in Fig. 3. The maximum distances from the array where sound levels of 190, 180, 170 and 160 dB re 1 µPa (rms) are predicted to be received are shown for the array in Table 1. The rms (root-mean-square) pressure is an average over the pulse duration. This is the measure commonly used in studies of marine mammal reactions to airgun sounds, and in NMFS guidelines concerning levels above which "taking" might occur. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a).

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[1] All source level estimates are for a filter bandwidth of approximately 0–250 Hz.

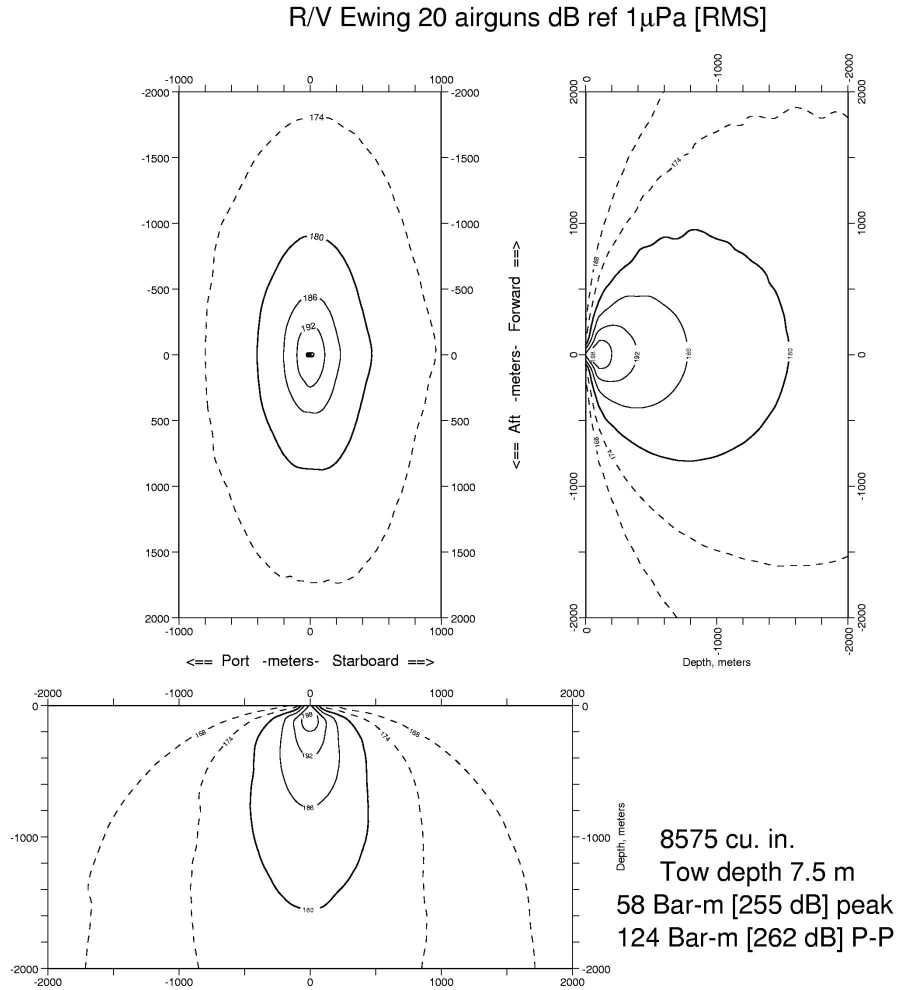

FIGURE 3. Modeled received sound levels from the 20-gun array that will be used during the seismic survey off the northern Yucatán Peninsula in the Gulf of Mexico, March–April 2004.

TABLE 1. Distances to which sound levels ≥ 190, 180, 170 and 160 dB re 1 µPa (rms) might be received from the 20-gun array that will be used during the proposed seismic survey north of the Yucatán Peninsula, Gulf of Mexico.

20-gun Array Volume	Airgun Depth in meters (ft)	Predicted RMS Radii in meters (ft)			
		190 dB	180 dB	170 dB	160 dB
8575 in^3	7.5 (25)	275 (902)	900 (2953)	2600 (8531)	9000 (29,529)

The predicted 190 and 180 dB (rms) distances (="safety radii") are expected to be verified prior to the Chicxulub Crater cruise, based on acoustical measurements during airgun operations in shallow waters within the northern Gulf of Mexico. Those measurements were obtained from 27 May to 3 June 2003 (see separate IHA application, EA, and 90-day report). LDEO's analysis of the acoustic data from that study is nearing completion; results are expected to be available during autumn 2003. The data will either confirm or be used to refine the safety radii to be used during this and future LDEO seismic studies.

When airgun operations commence after a period without airgun operations, the number of guns firing will be increased gradually ("ramped up", also described as a "soft start" in some jurisdictions; see § XI, "MITIGATION MEASURES"). Operations will begin with the smallest gun in the 20-gun array (80 in^3). Guns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~25 min for the 20-gun array. Throughout the ramp-up procedure, the safety zone will be defined as if the full 20-gun array were already in operation.

When a long streamer containing hydrophones is towed behind the vessel, the turning rate of the vessel is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during streamer operations. A streamer will be used during much of this project (Table 2).

Airgun Operations and OBS Deployment and Retrieval

The Chicxulub Crater cruise will consist of several different Experiments and Stages, including a high-resolution survey, Multi-Channel Seismic (MCS) profiles, and OBS deployments. A total of about 3313 km (1789 n.mi.) will be surveyed, including provision for turns (Table 2). The different stages are outlined below in the order that they are currently planned to take place.

TABLE 2. Total number of kilometers to be surveyed during various Stages of the Chicxulub Crater cruise.

Stage	Experiment	Total km surveyed with streamer	Total km surveyed without streamer	Turns	Total
1	A	225	255	144	624
2	C	675	-	-	675
3	B1	-	900	-	900
4	A	495	-	144	639
5	C	325			325
6	OBS	-	-	-	0
7	B2	150	-	-	150
Total		**1870**	**1155**	**288**	**3313**

Stage 1 (Regional Tomographic Survey - 1st half of Experiment A, Figs. 4 and 5)

During Stage 1, a total of 28 OBSs (black dots on gray lines in Fig. 5) will be deployed within a 52.5 × 37.5 km (28.2 × 20.2 n.mi.) grid. Air gun surveys will be done at a cross-line spacing of 3.75 km (2.0 n.mi.) along the grid lines shown in gray on Figure 5. A total of 480 km of grid lines will be surveyed; 225 km of surveying will use the hydrophone streamer as the receiver system, and 255 km of surveys will use OBSs as receivers (Table 3, Figs. 4 and 5). In addition to the 480 km of straight-line

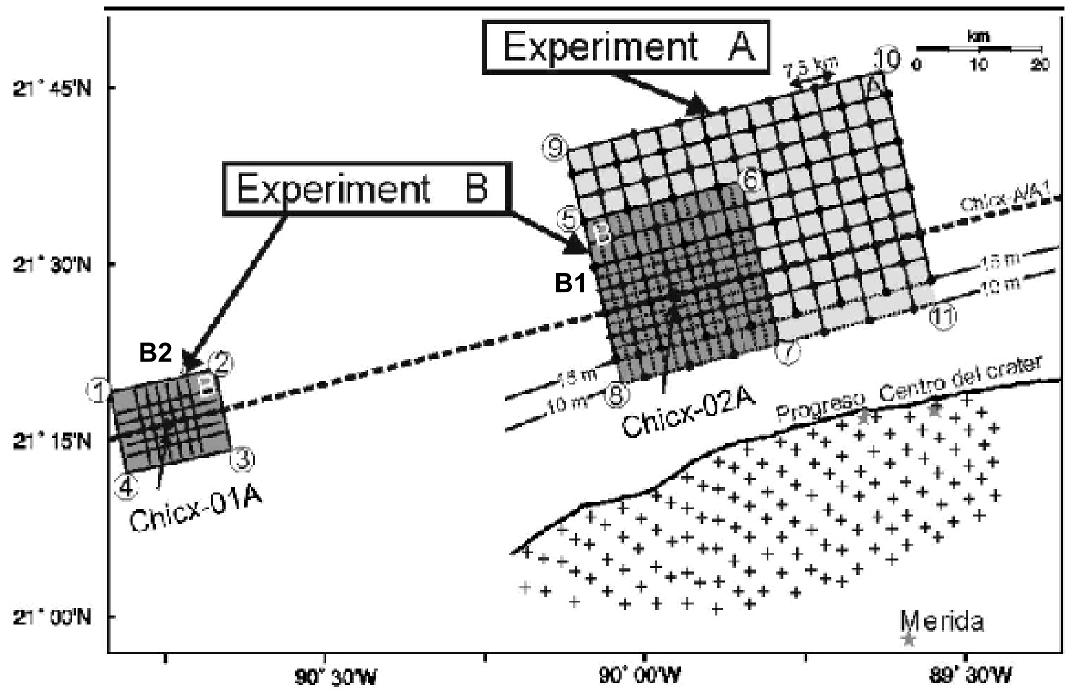

FIGURE 4. Tracklines and OBS deployments for the proposed seismic surveys for Experiments A and B to be conducted off the Yucatán Peninsula, Gulf of Mexico, March–April 2004. Experiment A is a regional tomographic survey, Experiment B1 consists of a high-resolution survey centered at the Ocean Drilling Program (ODP) drill site Chicx-02A, and Experiment B2 is a detailed survey centered at the ODP drill site Chicx-01A. Approximately 130–150 land receivers (shown as + signs) will record data from all shots.

surveys, an additional 144 km may be surveyed if operation of the full airgun array during turns is feasible. There will be 12 turns of ~12 km each, totaling 144 km in turns and bringing the overall total for Stage 1 to 624 km. It will take ~75 hrs of seismic operations and ~8 days to complete this stage, including streamer balancing and array set-up.

Stage 2 (Regional Multi-Channel Seismic Survey - Experiment C, Fig. 6)

Stage 2 will consist of a Multi-Channel seismic survey (shown as thick black lines in Fig. 6) using a 6-km towed hydrophone streamer. The survey will total 675 km, totaling 81 hrs of seismic operations. This stage will take ~4 days to finish.

Stage 3 (High Resolution Survey - Experiment B1, Figs. 4 and 5)

During Stage 3 of the cruise, 20 OBSs (and perhaps up to 40 OBSs denoted by circles and diamonds in gray shaded region of Fig. 5) will be recovered from their earlier locations and re-deployed within a 26.25 × 15 km (14.2 × 8.1 n.mi.) grid, with air gun profiles at a cross-line spacing of 1.875 km (1.0 n.mi.). No hydrophone streamer will be towed during Stage 3. A total of 900 km of high-resolution surveys will be conducted along the dotted lines in Fig. 5. This includes seismic operations during the tight turns that are possible in the absence of a streamer. The survey is expected to take 108 hours of seismic operation or ~6.5 days.

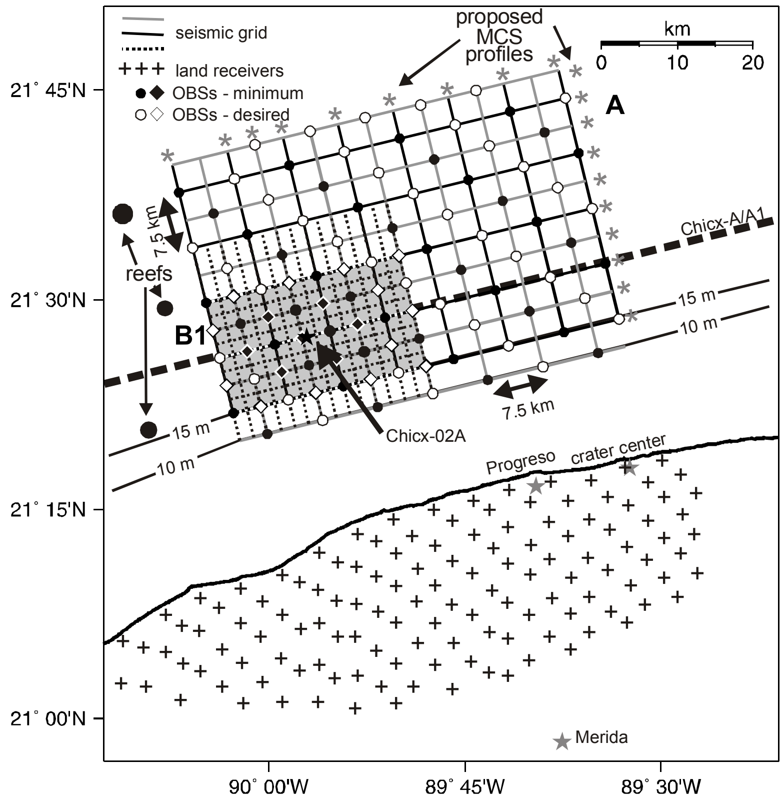

FIGURE 5. A more detailed map of the tracklines and OBS deployments for the proposed regional tomographic survey (Experiment A, Stages 1 and 4) and the high-resolution seismic survey (Experiment B1, Stage 3) to be conducted off the Yucatán Peninsula, Gulf of Mexico, March–April 2004. For Experiment A, the gray grid lines will be surveyed in Stage 1 and the black lines in Stage 4. The high-resolution survey will be centered at the ODP drill site Chicx-02A.

TABLE 3. Total number of kilometers to be surveyed during Stage 1.

Line direction*	Number of profiles	Number of km per profile	Total number of km to be surveyed	Acoustic signal receiver system
East-West	4	45	180	6-km hydrophone streamer
East-West	1	45	45	3-km hydrophone streamer
East-West	1	45	45	OBSs - no streamer
North-South	7	30	210	OBSs - no streamer

*The lines are shown on Fig. 5 in gray.

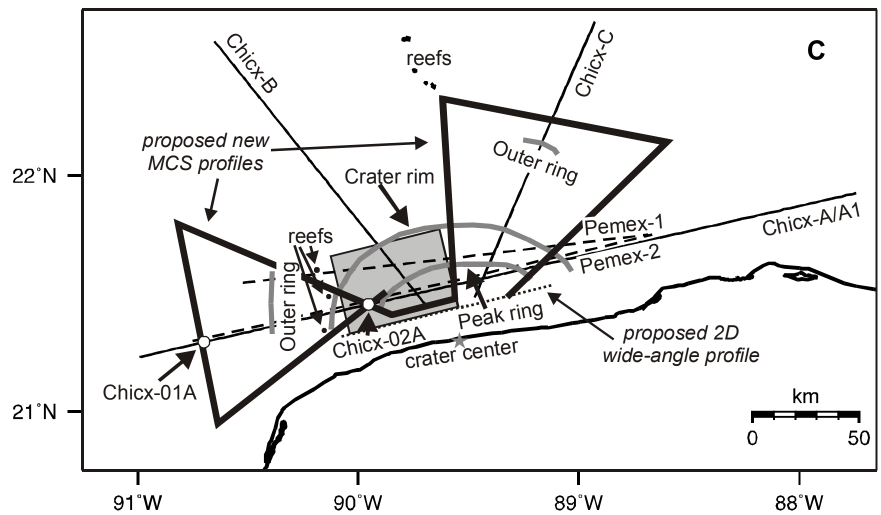

FIGURE 6. Tracklines for the proposed MCS seismic survey for Experiment C (Stages 2 and 5), to be conducted off the Yucatán Peninsula in the Gulf of Mexico from March to April 2004. The map shows the location of peak ring, crater rim, and outer ring as observed on existing MCS profiles (thin solid and dashed lines). The shaded box shows location of the high-resolution seismic survey (see Figs. 4 and 5 above). The thick solid lines show locations of proposed regional MCS profiles (Stage 2). The new profiles should give four additional crossings of the outer ring and crater rim, provide three new radial profiles, and provide crossing lines through the proposed ODP sites, Chicx-01A and Chicx-02A.

Stage 4 (Regional Tomographic Survey - 2nd half of Experiment A, Figs. 4 and 5)

During stage 4, 26 OBSs will be recovered and re-deployed. A total of 495 km of airgun surveys will be done along the black grid lines shown in Figure 5 (Table 4). In addition, another 144 km may be surveyed if operation of the full airgun array during turns is feasible. There will be 12 turns of ~12 km each, totaling 144 km during turns, or 639 km in total. It will take ~77 hrs of seismic operations and ~8 days to complete this stage.

Stage 5 (Radial MCS Survey - Experiment C)

This stage will consist of 325 km of surveying, towing a 6-km hydrophone streamer. The survey will require ~39 hours of seismic shooting, over a period of ~2 days.

TABLE 4. Total number of kilometers to be surveyed during Stage 4.

Line direction*	Number of profiles	Number of km per profile	Total number of km to be surveyed	Acoustic signal receiver system
East-West	4	45	180	6-km hydrophone streamer
East-West	1	45	45	3-km hydrophone streamer
North-South	9	30	270	3-km hydrophone streamer

*The lines are shown on Fig. 5 in gray.

Stage 6 (OBS recovery)

Stage 6 consists of recovering 28 OBSs, which will take ~1.5 days. No airgun operations are planned.

Stage 7 (Detailed survey - Experiment B2, Fig. 4)

A grid totaling 150 km, located to the west of the other components (Fig. 4), will be surveyed using the 3-km streamer. Total shooting time will be ~18 hrs, and will take ~1 day.

Multibeam Sonar and Sub-bottom Profiler

Along with the airgun operations, two additional acoustical data acquisition systems will be operated during much or all of the cruise. The ocean floor will be mapped with an Atlas Hydrosweep DS-2 multibeam 15.5-kHz bathymetric sonar, and a 3.5-kHz sub-bottom profiler will also be operated along with the multibeam sonar. These sound sources are commonly operated from the *Ewing* simultaneous with the airgun array.

Atlas Hydrosweep

This sonar is mounted in the hull of the *Ewing*, and it operates in three modes, depending on the water depth. There is one shallow water mode and there are two deep-water modes: an Omni mode and a Rotational Directional Transmission mode (RDT mode). ***(1)*** When water depth is <400 m, the source output is 210 dB re 1 µPa·m rms and a single 1-millisecond pulse or "ping" per second is transmitted, with a beamwidth of 2.67 degrees fore-aft and 90 degrees athwartship. The beamwidth is measured to the –3 dB point, as is usually quoted for sonars. ***(2)*** The Omni mode is identical to the shallow-water mode except that the source output is 220 dB rms. The Omni mode is normally used only during start up. ***(3)*** The RDT mode is normally used during deep-water operation and has a 237 dB rms source output. In the RDT mode, each "ping" consists of five successive transmissions, each ensonifying a beam that extends 2.67 degrees fore-aft and ~30 degrees in the cross-track direction. The five successive transmissions (segments) sweep from port to starboard with minor overlap, spanning an overall cross-track angular extent of about 140 degrees, with tiny (<<1 ms) gaps between the pulses for successive 30-degree segments. The total duration of the "ping", including all five successive segments, varies with water depth, but is 1 ms in water depths <500 m and 10 ms in the deepest water. For each segment, ping duration is $1/5^{th}$ of these values or $2/5^{th}$ for a receiver in the overlap area ensonified by two beam segments. The "ping" interval during RDT operations depends on water depth and varies from once per second in <500 m (1640.5 ft) water depth to once per 15 seconds in the deepest water.

Sub-bottom Profiler

This device is normally operated to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the Hydrosweep. The energy from the sub-bottom profiler is directed downward by a 3.5 kHz transducer mounted in the hull of the *Ewing*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. Pulse interval is 1 second but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

Sub-bottom Profiler Specifications

Maximum source output (downward)	204 dB re 1 µPa at 800 watts
Normal source output (downward)	200 dB re 1 µPa at 500 watts
Dominant frequency components	3.5 kHz
Bandwidth	1.0 kHz with pulse duration 4 ms 0.5 kHz with pulse duration 2 ms 0.25 kHz with pulse duration 1ms
Nominal beamwidth	30 degrees
Pulse duration	1, 2, or 4 ms

II. Dates, Duration and Region of Activity

The date(s) and duration of such activity and the specific geographical region where it will occur.

The *Ewing* is scheduled to depart from Progreso, Mexico, on 1 March will transit directly to the survey area off the northern Yucatán Peninsula (Fig. 1, 4). The seismic survey will commence following ~1 day of streamer, airgun, and OBS deployment and will last for ~31 days (Table 5). The equipment will be recovered at the end of the survey, and the vessel will transit back to Progreso for arrival on or about 4 April 2004. The exact dates of the activity may vary by a few days due to weather conditions, repositioning, streamer operations and adjustments, airgun deployment or the need to repeat some lines if data quality is substandard.

The seismic survey will take place over the Chicxulub Crater off the northern Yucatán Peninsula, in the Gulf of Mexico (Fig. 4). The overall area within which the seismic survey will occur is located between 21º and 22.5ºN and between 88º and 91ºW (Fig. 4).

TABLE 5. Duration of various stages of the seismic survey to be conducted in the Gulf of Mexico during March and April 2004.

Stage	Duration (days)
1	8
2	4
3	6.5
4	8
5	2
6	1.5
7	1
Total	**31**

III. Species and Numbers of Marine Mammals in Area

The species and numbers of marine mammals likely to be found within the activity area.

In the Gulf of Mexico, 28 cetacean species and one species of manatee are known to occur (Würsig et al. 2000). Seven of these species are listed as endangered under the U.S. Endangered Species Act (ESA), including the sperm, North Atlantic right, humpback, sei, fin, and blue whales, as well as the West Indian manatee. Any pinniped sighted in the study area would be extralimital.

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in Section IV, below.

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition.

A total of 28 cetacean species and one species of sirenian (West Indian manatee) are known to occur in the Gulf of Mexico (Jefferson and Schiro 1997; Würsig et al. 2000; Table 6). Of the 28 cetacean species, the Gulf distributions of three species may be limited to the northern Gulf of Mexico; these three species that may not occur in the project area are Sowerby's beaked whale *(Mesoplodon bidens*), the North Atlantic right whale (*Eubalaena glacialis*), and Bryde's whale (*Balaenoptera edeni*). In addition to the 28 species known to occur in the Gulf of Mexico, another three species of cetaceans could potentially occur there: the long-finned pilot whale (*Globicephala melas*), the long-beaked common dolphin (*Delphinus capensis*), and the short-beaked common dolphin (*Delphinus delphis*) (Table 6).

In the Gulf of Mexico, the southwestern Florida continental shelf and the narrow shelf south of the Mississippi River have been identified as important habitats for cetaceans (Baumgartner et al. 2001; Davis et al. 2002). Unlike the northern Gulf of Mexico, little is known about cetacean abundance and distribution in the southern Gulf; only opportunistic sightings and strandings have been reported (Jefferson and Lynn 1994; Jefferson and Schiro 1997; Würsig et al. 2000; Ortega-Ortiz 2002). Nonetheless, the diversity of cetaceans in the southern Gulf is likely similar to that observed in the northern Gulf (Ortega-Ortiz 2002).

The marine mammals that occur in the proposed survey area belong to three taxonomic groups: the odontocetes (toothed cetaceans, such as dolphins), the mysticetes (baleen whales), and sirenians (the West Indian manatee). The odontocetes and mysticetes are the subject of this IHA Application to the National Marine Fisheries Service; in the U.S., manatees are managed by the Fish & Wildlife Service.

TABLE 6. The habitat, abundance, and conservation status of marine mammals that are known to occur in the Gulf of Mexico. For species that occur commonly in the Gulf at water depths <200 m, the "habitat" and "Occurrence in Gulf of Mexico" entries are in boldface.

Species	**Habitat**	**Occurrence in Gulf of Mexico**[1]	**Abundance in Gulf and in North Atlantic**[2]	**ESA**[3]	**IUCN**[4]	**CITES**[5]
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	Common	530 (0.31)[a] *13,190* [b]	Endangered *	Vulnerable/ A1bd[†]	I
Pygmy sperm whale (*Kogia breviceps*)	Deeper waters off the shelf	Common	733[c,d] *536 (0.45)* [e,d]	Not listed	N.A.	II
Dwarf sperm whale (*Kogia sima*)	Deeper waters off the shelf	Common	N.A.	Not listed	N.A.	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Rare	159[c] *3196 (0.34)* [e,f]	Not listed	Data Deficient	II
Sowerby's beaked whale (*Mesoplodon bidens*)	Pelagic	Extralimital; not seen in southern Gulf	117 (0.38)[a,g]	Not listed	Data Deficient	II
Gervais' beaked whale (*Mesoplodon europaeus*)	Pelagic	Uncommon	N.A.	Not listed	Data Deficient	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	Rare	N.A.	Not listed	Data Deficient	II
Rough-toothed dolphin (*Steno bredanensis*)	Mostly pelagic	Common	852 (0.31)[a]	Not listed	Data Deficient	II
Bottlenose dolphin (*Tursiops truncatus*)	**Continental Shelf, coastal** and offshore	**Common**	5618 (0.26)[h] 50,247 (0.18)[I] 3499 (0.21)[j] 4191 (0.21)[k] 9912 (0.12)[m] 5141[n] *50,092* [e,o]	Not listed[§]	Data Deficient	II
Pantropical spotted dolphin (*Stenella attenuata*)	Mainly pelagic	Common	46,625[c] *13,117 (0.56)*[e]	Not listed	Lower Risk/ Conservation Dependent	II
Atlantic spotted dolphin (*Stenella frontalis*)	**Mainly coastal waters**	**Common**	3213[a] *52,279* [p]	Not listed	Data Deficient	II

Species	**Habitat**	**Occurrence in Gulf of Mexico**[1]	**Abundance in Gulf and in North Atlantic**[2]	**ESA**[3]	**IUCN**[4]	**CITES**[5]
Spinner dolphin (*Stenella longirostris*)	Pelagic in Gulf of Mexico	Common	11,251[c]	Not listed	Lower Risk/ Conservation Dependent	II
Clymene dolphin (*Stenella clymene*)	Pelagic	Common	10,093[c]	Not Listed	Data Deficient	II
Striped dolphin (*Stenella coeruleoalba*)	Off the continental shelf	Common	4858 (0.44)[a] *61,546 (0.40)*[e]	Not listed	Lower Risk/ Conservation Dependent	II
Short-beaked common dolphin (*Delphinus delphis*)	Continental shelf and pelagic waters	Possible	N.A.	Not listed*	N.A.	II[+]
Long-beaked common dolphin (*Delphinus capensis*)	Coastal	Possible	N.A.	Not Listed	N.A.	II[+]
Fraser's dolphin (*Lagenodelphis hosei*)	Water >1000 m	Common; has not been seen in study area	127 (0.90)[a]	Not listed	Data Deficient	II
Risso's dolphin (*Grampus griseus*)	Waters 400-1000 m	Common	3040[c] *29,110 (0.29)*[e]	Not listed	Data Deficient	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	Common	3965 (0.39)[a]	Not listed	N.A.	II
Pygmy killer whale (*Feresa attenuata*)	Oceanic	Uncommon	518 (0.81)[a]	Not listed	Data Deficient	II
False killer whale (*Pseudorca crassidens*)	Pelagic	Uncommon	817[c]	Not listed	N.A.	II
Killer whale (*Orcinus orca*)	Widely distributed	Uncommon	277 (0.42)[a] *6600* [q]	Not listed	Lower Risk/ Conservation Dependent	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic	Common	1471[c] *792,524* [r]	Not listed*	Lower Risk/ Conservation Dependent	II
Long-finned pilot whale (*Globicephala melas*)	Mostly pelagic	Possible	N.A.	Not listed*	N.A.	II
Mysticetes North Atlantic right whale (*Eubalaena glacialis*)	Coastal and shelf waters	Extralimital; not seen in southern Gulf	291[e]	Endangered *	Endangered/ C1,D[‡]	I

Species	**Habitat**	**Occurrence in Gulf of Mexico**[1]	**Abundance in Gulf and in North Atlantic**[2]	**ESA**[3]	**IUCN**[4]	**CITES**[5]
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore waters and banks	Rare	*11,570* [s] *10,600* [t] *10,000* [u]	Endangered *	Vulnerable/ A1ad[†]	I
Minke whale (*Balaenoptera acutorostrata*)	Coastal waters	Rare	*149,000* [v]	Not listed	Lower Risk/ Near Threatened	I
Bryde's whale (*Balaenoptera edeni*)	Pelagic and coastal	Uncommon; not seen in southern Gulf	35 (1.10)[a]	Not listed	Data Deficient	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	Rare	*12-13,000* [w]	Endangered *	Endangered/ A1abd[‡]	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	Rare	2814[e] *47,300* [v]	Endangered *	Endangered/ A1abd[‡]	I
Blue whale (*Balaenoptera musculus*)	Coastal, shelf, and oceanic waters	Extralimital	*308*[e,x]	Endangered *	Endangered/ A1abd[‡]	I
Sirenian West Indian manatee (*Trichechus manatus*)	Freshwater and coastal waters	Common along the coast of Florida; Rare in other parts of the Gulf	86[y] 340[z]	Endangered *	Vulnerable/ A2d[†]	I
Pinnipeds Hooded seal (*Cystophora cristata*)	Coastal	Vagrant	*300,000^*	Not listed	N.A.	N.A.

N.A. - Data not available or species status was not assessed.
[1] Occurrence from Würsig et al. (2000).
[2] Estimate for North Atlantic population shown in italics. The Coefficient of Variation (CV) is a measure of a number's uncertainty or variability on a proportional basis and is shown in brackets.
[3] Endangered Species Act (Waring et al. 2001, 2002).
[4] IUCN Red List of Threatened Species (2002).
[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2002).
* Listed as a strategic stock under the U.S. Marine Mammal Protection Act.
[§] Only the Gulf of Mexico bay, sound, and estuarine stocks are strategic.
[a] Abundance estimate for the northern Gulf of Mexico stock from Waring et al. (2001, 2002).
[b] *g*(o) corrected total estimate for the Northeast Atlantic, Faroes-Iceland, and the U.S. east coast (Whitehead 2002).

[c] Abundance estimate for the northern Gulf of Mexico stock from Davis et al. (2000).
[d] Estimate for *Kogia* sp.
[e] Abundance estimate for U.S. Western North Atlantic stocks (Waring et al. 2002).
[f] This estimate is for *Mesoplodon* and *Ziphius* spp.
[g] Estimate for all *Mesoplodon* spp. and perhaps including some *Ziphius* spp.
[h] Gulf of Mexico continental shelf edge and continental slope stock.
[i] Gulf of Mexico outer continental stock (Waring et al. 2002).
[j] Western Gulf of Mexico coastal stock (Waring et al. 2002).
[k] Northern Gulf of Mexico coastal stock (Waring et al. 2002).
[m] Eastern Gulf of Mexico coastal stock (Waring et al. 2002).
[n] Gulf of Mexico bay, sound, and estuarine stocks (Waring et al. 2002).
[o] Abundance estimate is a total for the Western North Atlantic offshore and coastal stock.
[p] Abundance estimate for the Western North Atlantic offshore and coastal stocks combined.
[q] Estimate for Icelandic and Faroese waters (Reyes 1991).
[r] This is a combined estimate for *Globicephala sp.* for the Northeast Atlantic (Buckland et al. 1993) and for the Western North Atlantic stock (Waring et al. 2002).
[s] This estimate is for the Atlantic Basin (Stevick et al. 2001, 2003).
[t] Estimate for the entire North Atlantic (Smith et al. 1999).
[u] Estimate for the Southern Hemisphere (IWC 2003).
[v] Estimate is for the North Atlantic (IWC 2003).
[w] Abundance estimate for the North Atlantic (Cattanach et al. 1993).
[x] Minimum abundance estimate.
[y] Antillean Stock in Puerto Rico only.
[z] Antillean Stock in Belize (Reeves et al. 2002).
[^] Estimate for the northwest Atlantic (Seal Conservation Society 2001).
[+] No distinction is made between *D. delphis* and *D. capensis.*
[†] The following criteria apply to the IUCN's Vulnerable category (as reported in the table):

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥ 50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   - (a) direct observation
   - (b) an index of abundance appropriate to the taxon
   - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
   - (d) actual or potential levels of exploitation
   - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of ≥30% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1

[‡] The following criteria apply to the IUCN's Endangered category (as reported in the table):

A. Reduction in population size based on

1. An observed, estimated, inferred or suspected population size reduction of ≥ 70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   - (a) direct observation
   - (b) an index of abundance appropriate to the taxon
   - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
   - (d) actual or potential levels of exploitation
   - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

C. Population estimated to number less than 2500 mature individuals and either

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, or
2 A continuing decline, observed, projected, or inferred, in numbers of mature individuals and population structure in the form of either
   - (a) severely fragmented (i.e. no subpopulation estimated to contain more than 250 mature individuals), or
   - (b) all individuals are in a single subpopulation.

D. Population estimated to number less than 250 mature individuals.

No species of pinnipeds are known to occur regularly in this region. Nonetheless, vagrant hooded seals could occur in the area. Hooded seals have been seen as far south as the Caribbean (Rice 1998; Mignucci-Giannoni and Odell 2001; Reeves et al. 2002). The Caribbean monk seal, *Monachus tropicalis*, has been extinct since the early 1950s; the last verified sighting in the Gulf of Mexico was in 1932 (Würsig et al. 2000). The California sea lion (*Zalophus californianus*), which was introduced to the Gulf of Mexico, has not been reported there since 1972 (Würsig et al. 2000).

Odontocetes

Numerous species of toothed whales occur in the Gulf of Mexico but most of these species occur predominantly in relatively deep offshore water (Table 6). Thus, most of the species discussed below are unlikely to be encountered during the present project, which will be in areas <100 m (<328 ft) deep, with about 99% in depths <50 m (<164 ft). Only two species of odontocetes, the bottlenose dolphin and Atlantic spotted dolphin, prefer the shallower waters of the Gulf of Mexico.

Sperm Whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). In the western North Atlantic, they are often seen along the continental shelf (Würsig et al. 2000). The sperm whale is the most abundant large whale in the Gulf of Mexico (Würsig et al. 2000). Adults as well as young sperm whales have been sighted in the Gulf (Würsig et al. 2000). It is likely that a resident population of sperm whales exists in the Gulf (Schmidly and Shane 1978 *in* Würsig et al. 2000), although year-round residency has not yet been confirmed in the area (Würsig et al. 2000). An ongoing study with satellite-linked tags (Mate in press) is likely to provide relevant information on this topic. The sperm whale is predominantly a deep-water species, and is unlikely to be encountered during the present shallow-water project.

In the northern Gulf, sperm whales are common in the central and eastern regions (Würsig et al. 2000). Concentrations of sperm whales occur south of the Mississippi River Delta, where upwelling is known to occur, in water 1000 m (3281 ft) deep (Mullin and Hoggard 2000; Würsig et al. 2000; Biggs et al. in press), and 300 km (162 n.mi.) east of the Texas-Mexico border (Würsig et al. 2000). Published information about the seasonal distribution and movements of sperm whales in the Gulf of Mexico is limited (Mate in press). However, a recent satellite tagging study showed that a sperm whale initially tagged in the northern Gulf of Mexico in 2001 spent 95 days there, before taking 23 days to traverse the upper Gulf, and proceeding to the Gulf of Campeche, Mexico, where it spent at least 19 days (Mate in press). A review by Ortega-Ortiz (2002) also showed the occurrence of sperm whales in the Gulf of Campeche. Interestingly, none of the 18 whales tagged in the northern Gulf in 2002 entered the Gulf of Campeche (Mate in press). The seasonal distribution of sperm whales in the Gulf of Mexico could be affected by year-to-year variation in the environment, such as an El Niño event, as well as individual variability (Mate in press). Strandings of sperm whales have also been reported for the southern Gulf at Antón Lizardo, Casitas and Tecolutla, Veracruz; San Felipe, Yucatán; and Isles Mujeres and Xcalac, Quintana Roo (see Ortega- Ortiz 2002).

Sperm whales generally occur in deep waters and along the continental slopes (Rice 1989; Ortega-Ortiz 2002). In the Gulf, they are most often seen along the lower continental slope, with water depths >1000 m or 3281 ft (Baumgartner et al. 2001; Davis et al. 2002). Sperm whales routinely dive to depths of hundreds of meters and may occasionally dive to depths of 9840 ft (3000 m) (Rice 1989). They are capable of remaining submerged for longer than two hours, but most dives are considerably shorter (Rice 1989). A telemetry study of a sperm whale in the southeast Caribbean conducted by Watkins et al. (2002)

showed that most dives were deep dives averaging 990 m (3248 ft) and ranged from 420–1330 m (1378–4364 ft). Deep dives lasted an average of 44.4 min, ranging from 18.2 to 65.3 min (Watkins et al. 2002). Thode et al. (2002) noted that sperm whale dives in the Gulf of Mexico usually last between 30 and 40 min; he also noted descent rates ranging from 79 to 96 m per min.

Sperm whales occur singly (older males) or in groups of up to 50 individuals. In the Gulf of Mexico, they have been seen singly or in groups (Mullin and Hoggard 2000). Biggs et al. (in press) noted that sperm whales in the north-central Gulf were mostly detected in groups of 2–9 animals. Weller et al. (1996) noted a group of 12 sperm whales in the Gulf, which were interacting with several short-finned pilot whales. Sperm whale distribution is thought to be linked to social structure; females and juveniles generally occur in tropical and subtropical waters, whereas males are wider ranging and occur in higher latitudes (Waring et al. 2001). Sperm whales are seasonal breeders, but the mating season is prolonged. In the Northern Hemisphere, conception may occur from January through August (Rice 1989), although the peak breeding season is from April to June (Best et al. 1984).

The sperm whale is the one species of odontocete discussed here that is listed under the U.S. Endangered Species Act (ESA), and the one species of odontocete that is listed in CITES Appendix I (Table 6). Although this species is formally listed as ***endangered*** under the ESA, it is a relatively common species on a worldwide basis, and is not biologically endangered. However, abundance in the Gulf of Mexico may be only on the order of five hundred animals (Davis et al. 2000; Waring et al. 2001, 2002). As noted above, these animals are unlikely to enter the relatively shallow waters where the planned project is to occur.

Pygmy Sperm Whale (*Kogia breviceps*)

Pygmy sperm whales are distributed widely in the world's oceans, but they are poorly known (Caldwell and Caldwell 1989). They are difficult to distinguish from dwarf sperm whales. Although there are few useful estimates of abundance for pygmy sperm whales anywhere in their range, they are thought to be fairly common in some areas.

In the western North Atlantic, pygmy sperm whales are known to occur from Nova Scotia to Cuba, and as far west as Texas in the Gulf of Mexico (Würsig et al. 2000). These whales are considered common in the Gulf and occur there year-round (Würsig et al. 2000). They strand frequently along the coast of the Gulf, especially in autumn and winter; this may be associated with calving (Würsig et al. 2000). In the northern Gulf, pygmy sperm whales are typically sighted in waters 100–2000 m (328–6562 ft) deep and their group sizes averaged 1.5 to 2.0 animals (range 1 to 6; Würsig et al. 2000). Densities of pygmy sperm whales were highest in the spring and summer and lower in the fall and winter (Würsig et al. 2000). Ten strandings of this species have been reported in the southern Gulf of Mexico and east coast of the Yucatán Peninsula: two in Tecolutla, Veracruz; one in Alvarado, Veracruz; Progreso and El Cuyo, Yucatán; Chitales, Cozumel (two strandings), Bahía de la Ascensión, and Cancún, Quintana Roo (see Ortega-Ortiz 2002).

These whales are primarily sighted along the continental shelf edge (Hansen et al. 1994; Davis et al. 1998), so are likely to be rare or absent in the majority of the planned survey area. Baumgartner et al. (2001) noted that they are sighted more frequently in areas with high zooplankton biomass. Pygmy sperm whales mainly feed on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). Pygmy sperm whales occur in small groups of up to six individuals (Caldwell and Caldwell 1989).

Dwarf Sperm Whale (*Kogia sima*)

Dwarf sperm whales are distributed widely in the world's oceans, but they are poorly known (Caldwell and Caldwell 1989). They are difficult to distinguish from pygmy sperm whales. Although there are few useful estimates of abundance for dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas. In the western North Atlantic, they are known to occur from Virginia to the Caribbean and the Gulf of Mexico (Würsig et al. 2000). These whales strand frequently along the coast of the Gulf, but not as frequently as pygmy sperm whales (Würsig et al. 2000). They are thought to occur in the Gulf year-round (Würsig et al. 2000). Five strandings of this species have been recorded in the southern Gulf of Mexico at Antón Lizardo, Veracruz; Las Colorados and El Cuyo (two strandings), Yucatán; and Tulúm, Quintana Roo (see Ortega-Ortiz 2002).

These whales are primarily sighted along the continental shelf edge and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998), so are likely to be rare or absent in the majority of the planned survey area. Baumgartner et al. (2001) noted that they are sighted more frequently in areas with high zooplankton biomass. Barros et al. (1998) suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales. Dwarf sperm whales mainly feed on squid, fish and crustaceans. Dwarf sperm whales may form groups of up to 10 animals (Caldwell and Caldwell 1989).

Cuvier's Beaked Whale (*Ziphius cavirostris*)

This cosmopolitan species is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). It appears to be absent from areas north of 60ºN and south of 50ºS (Würsig et al. 2000). In the western North Atlantic, these whales occur from Massachusetts to Florida, the West Indies, and the Gulf of Mexico (Würsig et al. 2000). In the Gulf of Mexico, they have been sighted on the lower continental slope where depths are about 2000 m (6562 ft) (Mullin and Hoggard 2000). Most strandings are from the eastern Gulf, especially from Florida (Würsig et al. 2000). Three strandings have been reported in the southern Gulf of Mexico at Campeche, and Holbox and Puerto Morelos, Quintana Roo (see Ortega-Ortiz 2002). Because of its preference for deep-water, the Cuvier’s beaked whale is unlikely to be encountered in the planned project.

This species is rarely observed and is mostly known from strandings (Leatherwood et al. 1976; NOAA and USN 2001). There are more recorded strandings for Cuvier's beaked whale than for other beaked whales (Heyning 1989). Its inconspicuous blow, deep-diving behavior, and its tendency to avoid vessels may help explain the rarity of sightings. Adult males of this species usually travel alone, but these whales can be seen in groups of up to 25 individuals. In the northern Gulf, group sizes ranged from 1 to 4 individuals (Mullin and Hoggard 2000). Calves are born year-round (Würsig et al. 2000). This species occurs offshore, and typically dives for 20–40 min in water up to 3300 ft (1000 m) deep. The stomach contents of stranded animals are primarily cephalopods, with occasional crustaceans and fish (Debrot and Barros 1994; MacLeod et al. 2003).

Sowerby's Beaked Whale (*Mesoplodon bidens*)

Sowerby's beaked whale occurs in cold temperate waters (Mead 1989). In the western North Atlantic, strandings have been recorded for Newfoundland, Massachusetts, and the Gulf of Mexico (Mead 1989). However, their occurrence in the Gulf is thought to be extralimital (Mead 1989; Würsig et al. 2000). Neither strandings nor sightings have been reported for the southern Gulf of Mexico (Ortega-Ortiz 2002).

Gervais' Beaked Whale (*Mesoplodon europaeus*)

The Gervais' beaked whale is mainly oceanic and occurs in tropical and warmer temperate waters of the Atlantic. The distribution of this species is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). Very little is known about the seasonality or other aspects of the reproduction of mesoplodonts. Mean length at birth has been estimated for three species (Mead 1984) and ranged from 2.10 m for *M. europaeus* to 2.50 m for *M. carlhubbsi* (40–48% of the maximum reported length of females of those species). In February 1953, a 4.20 m lactating female Gervais' beaked whale stranded with a 2.10 m calf (Rankin 1953). In another stranding incident, a female with a young calf stranded in Florida in October (Mead 1984). These incidents, and data from other *Mesoplodon* species, suggest that *M. europaeus* gives birth during autumn / winter.

Gervais' beaked whale is more frequent in the western than the eastern part of the Atlantic (Mead 1989), and occurs from New York to Florida and the Gulf of Mexico (Würsig et al. 2000). Strandings were reported in the Gulf of Mexico for Florida, Texas, the northeastern Gulf, Cuba, and southern Mexico (Würsig et al. 2000). Three strandings have been reported at Campeche in the southern Gulf of Mexico and Yucatán: Isla Aguada and Celestún, Campeche; and Chelum, Yucatán (see Ortega-Ortiz 2002). However, most records for the Gervais' beaked whale are from Florida (Debrot and Barros 1992).

Gervais' beaked whale usually inhabits deep waters (Davis et al. 1998). Food habits of this whale have been poorly studied, although Debrot and Barros (1992) noted that these animals likely feed in deep waters and show a preference for mesopelagic cephalopods and fish. Stomach contents have been known to include fish, squid, and mysids (Debrot 1998; Debrot et al. 1998; MacLeod et al. 2003).

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warmer temperate waters (Leatherwood and Reeves 1983). Houston (1990) reports that Blainville's beaked whale is widely, if thinly, distributed throughout the tropical and subtropical waters of the world. Blainville's beaked whales are rarely sighted, and most of the knowledge on the distribution of this species is derived from stranding data. In the western North Atlantic, it is found from Nova Scotia to Florida, the Bahamas, and the Gulf of Mexico (Würsig et al. 2000). Stranding records exist for Louisiana, Texas, Mississippi/Alabama, and Florida (Würsig et al. 2000), as well as for Sisal, Yucatán (see Ortega-Ortiz 2002).

There is no evidence that Blainville's beaked whales undergo seasonal migrations, although movements into higher latitudes are likely related to warm currents, such as the Gulf Stream in the North Atlantic. Blainville's beaked whale is mainly a pelagic species, and like other beaked whales, is mainly found in deep waters (Davis et al. 1998). However, Blainville's beaked whales may occur more frequently than other beaked whales in moderate-depth waters of 200–1000 m (MacLeod et al. 2003). These beaked whales travel in groups of 2 to 12 individuals, and dives can last up to 45 min. They appear to feed on mesopelagic squid and fish (Mead 1989; see also MacLeod et al. 2003).

Rough-toothed Dolphin (*Steno bredanensis*)

Rough-toothed dolphins are widely distributed around the world, but mainly occur in tropical and warm temperate waters (Miyazaki and Perrin 1994). In the western Atlantic, this species occurs between the southeastern United States and southern Brazil (Jefferson 2002). It has been sighted in the northern, and especially the eastern part of the Gulf, as well as in the southern Gulf (Würsig et al. 2000; Ortega-Ortiz 2002). Although this species does not tend to occur on the continental shelf in the northern Gulf (Jefferson and Schiro 1997), it is frequently seen on the continental shelf off Tabasco in the southern Gulf (see Ortega-Ortiz 2002). Strandings are known for Texas and Florida (Würsig et al. 2000), as well as in the southern Gulf at San Benito and Telchac, Yucatán; and Celestún and Punta Cam Balam, Campeche; 27 animals were involved in Campeche (see Ortega-Ortiz 2002). Rough-toothed dolphins are thought to occur year-round in the Gulf (Würsig et al. 2000).

Rough-toothed dolphins are generally found in moderate sized groups of 10–20 animals, but groups of up to 300 individuals have been seen in some areas (Jefferson 2002). In the Gulf, group sizes range from 2 to 48 individuals (Würsig et al. 2000). They are deep divers and can dive for up to 15 min (Reeves et al. 2002).

Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide, mostly in coastal waters, and is expected to be the most common species of dolphin in the project area. In the western North Atlantic, these dolphins occur from Nova Scotia to Florida, the Gulf of Mexico and the Caribbean, and southward to Brazil (Würsig et al. 2000). There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters, and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). Both types of bottlenose dolphins have been shown to inhabit waters in the western North Atlantic Ocean, including the Gulf of Mexico (Walker et al. 1999). In the Gulf, the inshore type inhabits shallow lagoons, bays and inlets, and the oceanic population occurs in deeper, offshore waters over the continental shelf (Würsig et al. 2000). The bottlenose dolphin is the most widespread and common cetacean in coastal waters of the Gulf of Mexico (Würsig et al. 2000). Bottlenose dolphins comprise most (71%) of the existing cetacean records in the southern Gulf of Mexico, mainly because they are common in coastal waters where most survey effort has been concentrated (Ortega-Ortiz 2002). Bottlenose dolphins are very common in the study area in shallow coastal waters.

Bottlenose dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m or 656 ft (Davis et al. 1998; 2002), but are also known to occur seaward of the shelf break at depths of 200–750 m or 656–2461 ft (Baumgartner et al. 2001). They can dive to depths of 1755 ft (535 m) for periods of up to 12 min (Schreer and Kovacs 1997). Bottlenose dolphins form groups that are organized on the basis of age, sex, familial relationship, and reproductive condition (Berta and Sumich 1999). Groups up to several hundred occur, but smaller pods of 2–15 are more common (Würsig et al. 2000). In the northern Gulf, group sizes are typically 1–90 (Mullin and Hoggard 2000). Group size is thought to be affected by habitat structure, and group size tends to increase with water depth (Würsig et al. 2000). Bräger (1993) found that bottlenose dolphins in the northern Gulf of Mexico show seasonal and diel patterns in their behavior. In the summer, they feed mainly during the morning and for a short time during the afternoon, and socializing increases as feeding decreases, with peak socializing in the afternoon (Bräger 1993). During the fall, they spend less time socializing and traveling, and feed throughout the day (Bräger 1993). During the summer, this species feeds mainly on fish, but during the winter, bottlenose dolphins in the northern Gulf of Mexico feed primarily on cephalopods and crustaceans (Bräger 1993).

Pantropical Spotted Dolphin (*Stenella attenuata*)

As its name indicates, the pantropical spotted dolphin can be found throughout tropical oceans of the world (Waring et al. 2001). In the western North Atlantic, it occurs from North Carolina to the West Indies and down to the equator (Würsig et al. 2000). It is the most common species of cetacean in the deeper Gulf of Mexico (Würsig et al. 2000). During 1989-1997, this species was mainly seen in the northcentral Gulf from south of the Mississippi Delta to west of Florida (Würsig et al. 2000). Several sightings have been reported for the southern Gulf of Mexico, on the continental slope as well as on the

Yucatán continental shelf (Ortega-Ortiz 2002). The presence of this species on the Yucatán shelf may be due to upwelling in the area (Ortega-Ortiz 2002).

Pantropical spotted dolphins usually occur in deeper waters, and in most areas rarely occur over the continental shelf or continental shelf edge (Davis et al. 1998; Waring et al. 2001). Baird et al. (2001) found that this species dives deeper at night than during the day, and that swimming speed also increased after dark. These results, together with the series of deep dives recorded immediately after sunset, suggest that pantropical spotted dolphins feed primarily at night on organisms associated with the deep-scattering layer as it rises toward the surface after dark (Baird et al. 2001).

Pantropical spotted dolphins are extremely gregarious and form schools of hundreds or even thousands of individuals. These large aggregations contain smaller groups that can consist of only adult females with their young, only juveniles, or only adult males (Perrin and Hohn 1994).

Atlantic Spotted Dolphin (*Stenella frontalis*)

This species is expected to be one of the two common species of dolphins in the project area, along with the bottlenose dolphin. Atlantic spotted dolphins are distributed in tropical and warm temperate waters of the western North Atlantic (Leatherwood et al. 1976). Their distribution extends from southern New England, south through the Gulf of Mexico and the Caribbean, to Venezuela (Leatherwood et al. 1976; Perrin et al. 1994a). They occur extensively off the Mexican Campeche Bank to the north and west of the Yucatán Peninsula (Würsig et al. 2000). There have been a number of sightings over the outer continental shelf in the southern Gulf of Mexico, along with some strandings (see Ortega-Ortiz 2002).

Atlantic spotted dolphins usually inhabit waters on the continental shelf inshore of the 250-m isobath (Davis et al. 1998; 2002). They move inshore in the spring and summer, perhaps associated with the arrival of carangid fish (Würsig et al. 2000). They mainly feed on fish, such as herring, anchovies, and flounder (Würsig et al. 2000). Davis et al. (1996) found that most dives of Atlantic spotted dolphins were shallow and of short duration, regardless of the time of day. Spotted dolphins usually dove to depths of 4 to <30 m, but the deepest dives recorded were 40–60 m or 131–197 ft (Davis et al. 1996). Most of the dives were less than 2 min in duration (Davis et al. 1996). This species can be seen in pods of up to 50 or more animals, but smaller groups of 6–10 animals are more common (Würsig et al. 2000). In the Gulf, group sizes range from 1 to 85 individuals (Mullin and Hoggard 2000).

Spinner Dolphin (*Stenella longirostris*)

Spinner dolphins are distributed in oceanic and coastal tropical waters. Although the spinner dolphin is generally an offshore, deep-water species, its distribution in the Atlantic is mostly unknown (Waring et al. 2001). In the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, Gulf of Mexico, and southward to Venezuela (Würsig et al. 2000). Almost all sightings in the Gulf of Mexico have been made east and southeast of the Mississippi Delta, in areas deeper than 100 m or 328 ft (Würsig et al. 2000). Strandings have been reported along the northern Yucatán Peninsula, including a mass stranding of 24 individuals at Dzilam de Bravo and a stranding at El Cuyo (see Ortega-Ortiz 2002). In addition, four sightings have been recorded in the southern Gulf: one over the continental shelf off Veracruz and the other three on the Campeche Bank northwest of the Yucatán Peninsula (see Ortega-Ortiz 2002). One of these sightings occurred in the study area in the spring.

Spinner dolphins typically inhabit deep waters (Davis et al. 1998). This species is extremely gregarious and usually forms large schools when in the open sea and small ones in coastal waters (Perrin and Gilpatrick 1994). Spinner dolphins can be seen in groups of 30 to hundreds of individuals, or even thousands (Würsig et al. 2000). In the Gulf, they have been sighted in groups of 9 to 750 individuals

(Würsig et al. 2000). They often travel in mixed-groups with pantropical spotted dolphins and other species (Perrin 2002). They usually feed at night on mesopelagic fish, squid, and shrimp that are in waters 200–300 m (656–984 ft) deep (Perrin and Gilpatrick 1994).

Clymene Dolphin (*Stenella clymene*)

Clymene dolphins usually occur in tropical and warm waters of the Atlantic Ocean. These animals are found off the eastern United States (including the Gulf of Mexico), south to Brazil, and across the Atlantic to West Africa (Mullin et al. 1994a; Fertl et al. 2003). In the Gulf of Mexico, they are widely distributed in the western oceanic Gulf during spring and the northeastern Gulf during summer and winter (Würsig et al. 2000). There are no records in the southern Gulf of Mexico and only two records from the northeastern Yucatán Peninsula (see Ortega-Ortiz 2002; Fertl et al. 2003). Given this, plus their preference for deep waters (see below), they are unlikely to be encountered during the planned project.

Clymene dolphins typically inhabit areas where sea surface temperatures range from 22.8 to 29.1^{o}C and water depths from 704 to 3064 m or 2310 to 10,053 ft (Mullin et al. 1994a; Davis et al. 1998). However, there are a few records in shallower waters (Fertl et al. 2003). They usually feed on small mesopelagic fish and squid (Perrin and Mead 1994). Composition of pods, based on mass strandings, has shown evidence of sexual segregation, i.e., groups tend to consist largely of one sex or the other (Jefferson et al. 1995). The estimated pod size for these dolphins is usually 2 to 100 animals, although larger pods occasionally occur (Mullin et al. 1994a; Würsig et al. 2000; Fertl et al. 2003).

Striped Dolphin (*Stenella coeruleoalba*)

Striped dolphins have a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994b). In the western North Atlantic, this species occurs from Nova Scotia to the Gulf of Mexico and south to Brazil (Würsig et al. 2000). A concentration of striped dolphins is thought to exist in the eastern part of the northern Gulf, near the DeSoto Canyon just east of the Mississippi Delta (Würsig et al. 2000). Two strandings have been reported in the southern Gulf in Veracruz and El Cuyo, Yucatán (see Ortega-Ortiz 2002).

Striped dolphins are pelagic and seem to prefer the deep water along the edge and seaward of the continental shelf (Davis et al. 1998). However, they do occur in coastal waters (Isaksen and Syvertsen 2002). They prey on small fish and small cephalopods (Perrin et al. 1994b). Striped dolphins are gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). School composition varies and consists of adults, juveniles, or both adults and juveniles (Perrin et al. 1994b). Their breeding season has two peaks, one in the summer and one in the winter (Boyd et al. 1999).

Short-beaked Common Dolphin (*Delphinus delphis*) and
Long-beaked Common Dolphin (*Delphinus capensis*)

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). The two species of common dolphins have only recently been distinguished. The short-beaked common dolphin is known to occur from Iceland and Newfoundland southward along the coast of the United Sates (Würsig et al. 2000). The long-beaked common dolphin occurs in coastal waters from Venezuela to Argentina (Perrin 2002). The two species are sometime difficult to distinguish at sea. There have not been any confirmed sightings of either species in the Gulf of Mexico, although they might occur in the southern Gulf (Würsig et al. 2000).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical species that only rarely occurs in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994c). Fraser's dolphins have been sighted in the northwestern Gulf, and have been found stranded in Florida and Texas (Würsig et al. 2000). One sighting record exists for the central western Gulf of Mexico (Leatherwood et al. 1993), but no sightings exist for the study area (Ortega-Ortiz 2002).

Fraser's dolphins typically occur in water at least 1000 m (3281 m) deep. They feed on mesopelagic fish, shrimp, and squid, diving to depths of at least 250–500 m or 820–1641 ft (Dolar 2002). They travel in groups ranging from just a few animals to hundreds or even thousands of individuals (Perrin et al. 1994c), often mixed with other species (Culik 2002).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. In the Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999). It has been sighted off Florida and in the western Gulf off the coast of Texas (Würsig et al. 2000). It is likely a year-round resident in the Gulf (Würsig et al. 2000). In the past, Risso's dolphins were sighted in continental slope waters of the Gulf in waters 200–1530 m (656–5020 ft) deep (Würsig et al. 2000). However, in recent years, most sightings in the northern Gulf occurred in waters of 200 m (656 ft) depth south of the Mississippi Delta (Würsig et al. 2000). Stranding records exist for Texas and Florida (Würsig et al. 2000). In the southern Gulf of Mexico, two strandings have been reported at Alvarado in Veracruz and Telchac in Yucatán, and there are no confirmed sightings (see Ortega-Ortiz 2002).

Risso's dolphins occur individually or in small to moderate-sized groups, normally ranging in numbers from two to less than 250, although groups as large as 4000 have been sighted. The majority of groups consist of fewer than 50 individuals (Kruse et al. 1999). They usually feed on squid and other deepwater prey (Kruse et al. 1999).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is a pantropical and pelagic species (Perryman et al. 1994), ranging from the Gulf of Mexico to southern Brazil in the western Atlantic (Rice 1998). These whales occur mainly between 20ºN and 20ºS; occasional occurrences in temperate regions are likely associated with warm currents (Perryman et al. 1994; Reeves et al. 2002). In the Gulf, they have been sighted in the northwest in waters 200–2000 m (656–6562 ft) deep, from Texas to Mississippi (Würsig et al. 2000). Strandings have also been reported for Texas and Louisiana (Würsig et al. 2000). The only record of this species in the southern Gulf of Mexico is an individual that was entangled in fishing line off Tuxpan, Veracruz, in water ~200 m (656 ft) deep (Ortega-Ortiz 2002).

Melon-headed whales are oceanic and occur in offshore areas (Perryman et al. 1994), as well as around oceanic islands. Mullin et al. (1994b) noted that they are usually sighted in water >500 m (1640 ft) deep, and away from the continental shelf. Melon-headed whales tend to travel in large groups of 100 to 500 individuals, but have also been seen in herds of 1500 to 2000 individuals. Melon-headed whales may also form mixed species pods with Fraser's dolphins, spinner dolphins, and spotted dolphins (Jefferson et al. 1993; Carwardine 1995). They appear to feed on squid, fish, and shrimp (Jefferson and Barros 1997; Perryman 2002), although squid appear to be the preferred prey of melon-headed whales (Perryman 2002).

Pygmy Killer Whale (*Feresa attenuata*)

Pygmy killer whales are pantropical (Ross and Leatherwood 1994; Rice 1998). They inhabit deep, warm waters from the Gulf of Mexico to Uruguay in the western Atlantic (Rice 1998). In the western North Atlantic, they occur from the Carolinas to Texas and the West Indies (Würsig et al. 2000). They are thought to occur in the Gulf of Mexico year-round (Würsig et al. 2000). They have been sighted in the Gulf off Texas and in the west-central portion of the northern Gulf, in water 500–1000 m (1640–3281 ft) deep (Würsig et al. 2000). Strandings have also occurred from Florida to Texas, with most strandings occurring in the winter (Würsig et al. 2000). In the southern Gulf of Mexico, two strandings have been reported at Tampico in Tamaulipas and Punta Villa Rica in Veracruz (see Ortega-Ortiz 2002).

Pygmy killer whales tend to travel in groups of 15–50 individuals, although herds of a few hundred have been sighted (Ross and Leatherwood 1994). The remains of fishes and squid have been found in the stomachs of stranded pygmy killer whales, and they are suspected to attack and sometimes eat other dolphins (Donahue and Perryman 2002).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer, temperate oceans, especially in deep offshore waters (Odell and McClune 1999). In the western North Atlantic, they occur from Maryland to the Gulf of Mexico and the Caribbean (Würsig et al. 2000). These animals have been sighted in the northern Gulf in waters 200–2000 m (656–6562 ft) deep (Würsig et al. 2000), especially in the eastern regions (Mullin and Hoggard 2000). They are also known to strand in the Gulf; records exist for Cuba, Florida, Louisiana, Texas, and southern Mexico (Würsig et al. 2000). In the southern Gulf of Mexico, strandings of up to 79 individuals have been reported at Alacranes Reef; Cancún, Campeche; El Cuyo, Yucatán; and Veracruz (see Ortega-Ortiz 2002). Individuals have also been sighted in the Yucatán Channel (see Ortega-Ortiz 2002).

False killer whales are primarily seen in deep, offshore waters, although sightings have been reported for shallow (<200 m or <656 ft) waters. They are gregarious and form strong social bonds (Stacey and Baird 1991). They travel in pods of 20–100 individuals (Baird 2002b), although groups of several hundred are sometimes observed. Recently stranded groups ranged from 28 to over 1000 animals. False killer whales feed primarily on fish and cephalopods, but have been known to attack small cetaceans, California sea lions (S.F. MacLean, LGL Ltd., pers. comm.), and even a humpback whale (Jefferson et al. 1993).

Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan and are fairly abundant, globally. Killer whales can be seen from equatorial regions to the polar pack-ice, and they may even ascend rivers. Killer whales are most common in high latitudes, especially in cooler areas where productivity is high. In the western North Atlantic, killer whales occur from the polar ice pack to Florida and the Gulf of Mexico (Würsig et al. 2000). In the Gulf, most sightings have been in waters 200–2000 m (656–6562 ft) deep southwest of the Mississippi Delta (Würsig et al. 2000). There have also been summer reports of these whales off Texas near the 200 m (656 ft) isobath (Würsig et al. 2000). In the southern Gulf of Mexico, there have been three stranding events along the northern Yucatán Peninsula and one sighting beyond the continental shelf in the Bay of Campeche (see Ortega-Ortiz 2002).

Killer whales are segregated socially, genetically, and ecologically into three distinct groups, residents, transients, and offshore animals. Resident groups feed exclusively on fish, while transients feed exclusively on marine mammals. Offshore killer whales are less known, and their feeding habits are not strictly defined. Killer whale movements generally appear to follow the distribution of prey.

Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Sightings range from the surf zone to the open sea, though usually within 800 km (432 n.mi.) of shore. Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999).

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

Short-finned pilot whales probably have a circumglobal distribution in tropical and warm temperate waters, generally south of 50ºN and north of 40º south (Jefferson et al. 1993; Rice 1998). They occur in deep water at the edge of the continental shelf and over deep submarine canyons (Carwardine 1995). There is some overlap of range with *G. melas*, although *G. macrohynchus* appears to have a more southerly distribution. Water temperature appears to be the primary factor determining the relative distribution of these two species (Fullard et al. 2000).

In the western North Atlantic, this species occurs from Virginia to northern South America, including the Caribbean and Gulf of Mexico (Würsig et al. 2000). They are likely to occur in the Gulf year-round (Würsig et al. 2000). In the northern Gulf, they are most commonly seen in the central and western areas in waters 200–1000 m (656–3281 ft) deep on the continental shelf slope (Würsig et al. 2000). In the southern Gulf, sightings mainly occur on the continental slope, and strandings are most frequently reported for the northern Yucatán Peninsula and surrounding islands (see Ortega-Ortiz 2002).

Short-finned pilot whales appear to form relatively stable, matrilineal groups of up to several hundred individuals (Jefferson et al. 1993) that are generally nomadic. There do not appear to be fixed migrations, but general north-south or inshore-offshore movements occur in relation to prey distribution or incursions of warm water. Short-finned pilot whales are primarily adapted to feeding on squid (Hacker 1992), although they also take some fishes.

Long-finned Pilot Whale (*Globicephala melas*)

Long-finned pilot whales occur in the temperate North Atlantic (Bernard and Reilly 1999). Although there are no records of long-finned pilot whales in the Gulf, they occur as far south as Georgia, on the eastern coast of the United States (Würsig et al. 2000). Thus, it is possible that extralimital strays may occur in the Gulf (Würsig et al. 2000).

Mysticetes

North Atlantic Right Whale (*Eubalaena glacialis*)

North Atlantic right whales occur from about 30º to 75ºN (Cummings 1985b). In the western North Atlantic, right whales are found from Iceland to Florida; their occurrence in the Gulf of Mexico is extralimital (Würsig et al. 2000). There have only been two accounts of right whales in the Gulf of Mexico—one sighting of two whales off Florida, and a stranding of a calf or young-of-the-year off the coast of Texas (Würsig et al. 2000). Right whales spend the spring and summer at high latitudes where they feed, and migrate south for mating and calving in the winter (Cummings 1985b). It is highly improbable that this species would be encountered near the Yucatán Peninsula in March–April.

The number of North Atlantic right whales in the western North Atlantic is estimated at only 291 animals (Waring et al. 2002). The right whale is listed as ***endangered*** under the ESA and by IUCN, and it is listed in CITES Appendix I (Table 6).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a cosmopolitan distribution. Although it is considered to be a mainly coastal species, it often traverses deep pelagic areas while migrating. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). In the western North Atlantic, it occurs from Greenland to Venezuela (Würsig et al. 2000). The majority of humpbacks from the North Atlantic population overwinter in the West Indies (Smith et al. 1999). The western North Atlantic population has been estimated to contain 5930–12,580 individuals, with a best estimate of 10,752 for 1992–93 (Stevick et al. 2003).

Although humpbacks only occur rarely in the Gulf of Mexico, several sightings have been made off the west coast of Florida, near Alabama, and off Texas (Würsig et al. 2000); these may have been individuals from the West Indian winter grounds that strayed into the Gulf during migration (Weller et al. 1996; Jefferson and Schiro 1997). Only one record of a humpback whale exists for the southern Gulf of Mexico, on the lower slope off Tuxpan (Ortega-Ortiz 2002). Although now relatively common, the humpback whale is listed as ***endangered*** under the ESA and in Appendix I of CITES (Table 6).

Minke Whale (*Balaenoptera acutorostrata*)

Minke whales have a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). Although widespread and common overall, they are rather rare in the Gulf of Mexico; however, stranded animals have been found in the Gulf on several occasions (Würsig et al. 2000). These strandings occurred in the winter and spring and may have been northbound whales from the open ocean or Caribbean Sea (Würsig et al. 2000). The only record of a minke whale in the southern Gulf of Mexico was a single whale recorded as stranded at Celestún, on the northwestern coast of the Yucatán Peninsula (see Ortega-Ortiz 2002).

Minke whales migrate northward during spring and summer and can be seen in pelagic water at this time; however, they also occur in coastal areas (Stewart and Leatherwood 1985). Minke whales seem able to find and exploit small and transient concentrations of prey (including both fish and invertebrates) as well as the more stable concentrations that attract multi-species assemblages of large predators. Minke whales are relatively solitary, but usually occur in aggregations of up to 100 animals when food resources are concentrated.

Bryde's Whale (*Balaenoptera edeni*)

Bryde’s whale is found in tropical and subtropical waters throughout the world, but rarely in latitudes above 35º. It is the most common mysticete in the tropics (Debrot 1998). The Bryde's whale is the most common baleen whale in the Gulf of Mexico (Würsig et al. 2000), but it does not appear to occur in the southern Gulf of Mexico (Ortega-Ortiz 2002). This species seems to occur in the Gulf year-round (Würsig et al. 2000). Bryde’s whale does not undertake long migrations, although it may move closer to the equator in winter and toward temperate waters in the summer (Best 1975 *in* Cummings 1985a). However, Debrot (1998) noted that this species is sedentary in the tropics. Bryde's whales are pelagic as well as coastal. In the northern Gulf, they are often sighted in relatively shallow water about 100 m or 328 ft deep (Davis et al. 1998, 2002). In the Gulf of Mexico, Bryde's whales occur singly or in groups of up to seven individuals (Mullin and Hoggard 2000).

Sei Whale (*Balaenoptera borealis*)

The sei whale has a cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The sei whale is listed as ***endangered*** under the U.S. Endangered Species Act. The global population is thought to be low, with about 2600 individuals in the western North Atlantic (Würsig et al. 2000). In that area, sei whales occur from the Caribbean and Gulf of Mexico to Newfoundland (Würsig et al. 2000). Sei whales are only seen rarely in the Gulf of Mexico (Würsig et al. 2000). There is one record of this species in the southern Gulf of Mexico, likely near Campeche (Miller 1928 *in* Ortega-Ortiz 2002).

Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985b), but typically occur in temperate and polar regions. Their population size in the western North Atlantic is estimated at 3600–6300 animals (Würsig et al. 2000). The fin whale is listed as ***endangered*** under the U.S. Endangered Species Act. They appear to have complex seasonal movements, and are likely seasonal migrants (Gambell 1985b). Fin whales mate and calve in temperate waters during the winter, but migrate to northern latitudes during the summer to feed (Mackintosh 1965 *in* Gambell 1985b). Their wintering range extends from the ice edge to the Caribbean. Fin whales are only rarely seen in the Gulf of Mexico and their occurrence is considered accidental. In the Gulf of Mexico, there have been reports of five strandings in the Gulf and up to seven sightings (Würsig et al. 2000). In the southern Gulf of Mexico, a fin whale was sighted at the Campeche escarpment (Ortega-Ortiz 2002).

Blue Whale (*Balaenoptera musculus*)

The blue whale is widely distributed throughout the world's oceans, and occurs in coastal, shelf and oceanic waters. Its distribution, at least during times of the year when feeding is a major activity, is specific to areas that provide large seasonal concentrations of euphausiids, which are the blue whale's main prey (Yochem and Leatherwood 1985). The population size in the North Atlantic is estimated at a few hundred (Würsig et al. 2000). Even though these whales are globally distributed, blue whales are unlikely to be seen in the Gulf of Mexico. Only two reports of blue whales exist for the northern Gulf of Mexico (Würsig et al. 2000). One stranded animal was found on the Texas coast, and another stranded animal was seen in Louisiana (Würsig et al. 2000). Another stranding of a blue whale was reported by Jefferson and Schiro (1997 *in* Orega-Ortiz 2002) at Veracruz in the southern Gulf of Mexico.

Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983). All populations of blue whales have been exploited commercially, and many have been severely depleted as a result. The blue whale is listed as ***endangered*** under the ESA and by IUCN, and is listed in CITES Appendix I (Table 6).

Sirenian

West Indian Manatee (*Trichechus manatus manatus*)

The West Indian manatee occurs in rivers, estuaries, lagoons, and coastal waters from the southeastern United States to Brazil. West Indian manatees have a patchy coastal distribution that is dependent on suitable habitat, including vegetation and fresh water; their numbers are locally reduced due to habitat change, hunting, and fisheries (Lefebvre et al. 1989).

Manatees swim slowly just below or at the surface of the water, and thus they are vulnerable to boat collisions. They feed on a variety of sea grasses and other vegetation. The West Indian manatee is capable of hearing sounds from 15 Hz to 46 kHz, with the best sensitivity at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

The West Indian manatee is subdivided into two subspecies, the Florida manatee (*Trichechus manatus latirostris*) and the Antillean manatee (*T. m. manatus*). The Antillean stock of the West Indian manatee is listed under the ESA as ***endangered***, and is a CITES Appendix I species. The manatee is the one species of marine mammal occurring in the area of concern that, in the U.S.A., is managed by the Fish & Wildlife Service rather than NMFS.

The Antillean manatee occurs in the Greater Antilles, northern and eastern South America, as well as Central America and eastern Mexico (Lefebvre et al. 1989). Except for the Florida coast, manatees are considered rare in the Gulf of Mexico (Würsig et al. 2000). Nonetheless, manatees do occur along the coast of Mexico, from Nautla, Veracruz, to the Belize border, especially in the wetlands of Tabasco and Chiapas, the bays of Quintana Roo, and the rivers near Alvarado, Veracruz (Reeves et al. 1992; Morales-Vela et al. 2003). Small numbers also occur in the Soto la Marina and Palmas rivers in northeastern Mexico (Reeves et al. 1992).

Manatees were once abundant in the northern and western Yucatán Peninsula, but are now rarely seen in that area (see Morales-Vela et al. 2003). Possible causes of the population decline include hunting, fishing, and hurricanes (Morales-Vela et al. 2003). Few sightings have been reported for the northern and western Yucatán Peninsula in the last 10 years, and persons interviewed in the area did not report any manatee sightings from 1994 to 1999 (Morales-Vela et al. 2003). The most recent reports in the area are of dead calves found at Progreso and Ciudad del Carmen, and a sighting at Lerma, on the central-western coast of the Yucatán Peninsula (Morales-Vela et al. 2003). In addition, Morales-Vela et al. (2003) did extensive aerial surveys on the north and west coasts of the Yucatán Peninsula and sighted a single manatee in Términos Lagoon, southern Campeche. Manatees are unlikely to be in the vicinity of the planned survey.

Pinniped

Hooded Seal (*Cystophora cristata*)

Hooded seals inhabit the pack ice zone of the North Atlantic from Baffin Bay, Denmark Strait, northern Greenland Sea, and the Barents Sea, south to the Gulf of St. Lawrence and Newfoundland, southern Greenland, Iceland, and Jan Mayen (Rice 1998). Hooded seals often wander great distances from their pack-ice habitat. They have been reported as far away as southern California in the Pacific; Florida, Puerto Rico, and the Virgin Islands in the western Atlantic; and the Iberian Peninsula in the eastern Atlantic (Lavigne and Kovacs 1988; Rice 1998; Mignucci-Giannoni and Odell 2001). Thus, vagrant hooded seals could occur in the proposed project area, but if so, they would be extralimital.

V. Type of Incidental Take Authorization Requested

The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

LDEO requests an Incidental Harassment Authorization pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act for incidental take by harassment during its planned seismic survey off the northern Yucatán Peninsula, Gulf of Mexico, from March to April 2004.

The operations outlined in Sections I and II have the potential to take marine mammals by harassment. Sounds will be generated by the airgun array used for the seismic survey, by a multibeam bathymetric sonar and sub-bottom profiler, and by general vessel operations. "Takes" will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airgun array or sonar. The effects will depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and level of the sound relative to ambient conditions. Disturbance reactions are likely among some of the marine mammals in the general vicinity of the tracklines of the survey vessel. No take by serious injury is anticipated, given the mitigation measures that are planned (see § XI, "MITIGATION MEASURES"). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

The anticipated impact of the activity upon the species or stock of marine mammal.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

- First we describe the potential impacts on marine mammals of airgun operations, sonar operations, and sub-bottom profiler operations, as called for in Section VII. ***This background material appears in subsections VI/VII (a) through (j), and is little changed from that included in related IHA Applications and EAs for other LDEO projects during 2003 and early 2004.*** Those documents concerned LDEO projects in the following areas: northern Gulf of Mexico, Hess Deep (eastern tropical Pacific), Norway, Mid-Atlantic Ocean, Bermuda, and Southeast Caribbean.
- Then, in subsection VI/VII (k), we estimate the numbers of marine mammals that might be affected by the proposed activity off the Yucatán Peninsula. The latter section includes a description of the rationale for LDEO's estimates of the potential numbers of harassment "takes" during the proposed seismic survey, as called for in Section VI.

(a) Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioral response;
3. The noise may elicit behavioral reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions;

4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, the intermittent airgun and sonar pulses that will be broadcast during the proposed survey could cause masking for only a small proportion of the time, given the short duration of airgun and sonar pulses relative to the inter-pulse intervals;
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

(b) Hearing Abilities of Marine Mammals

The hearing abilities of marine mammals are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold at the frequency in question (the level of sound barely audible in the absence of ambient noise).
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency).
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (reviewed in Chapter 8 of Richardson et al. (1995) and in Au et al. (2000). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kilohertz (kHz), but extremely good sensitivity at, and above, several kHz. There are at present no specific data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that small odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The multibeam sonar operated from the *Ewing* emits pulsed sounds at 15.5 kHz. That frequency is within or near the range of best sensitivity of many odontocetes. Thus, sound pulses from the multibeam sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioral and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are almost certainly more sensitive to low-frequency sounds than are the ears of the small toothed whales. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic (or sonar) sounds would be detectable and yet often show no overt reaction to those sounds. Behavioral responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioral reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995; McCauley et al. 2000a; Johnson 2002).

Pinnipeds

Underwater audiograms have been obtained using behavioral methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, higher auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30–50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 µPa. Measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1 µPa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal (not an Atlantic/Gulf of Mexico species) appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

For the otariid (eared) seals, the high frequency cutoff is lower than for phocinids, and sensitivity at low frequencies (e.g., 100 Hz) is poorer than for hair seals (harbor or elephant seal).

The underwater hearing of a walrus has recently been measured at frequencies from 125 Hz to 15 kHz (Kastelein et al. 2002). The range of best hearing was from 1–12 kHz, with maximum sensitivity (67 dB re 1 µPa) occurring at 12 kHz (Kastelein et al. 2002).

Sirenians

The hearing of manatees is sensitive at frequencies below 3 kHz. A West Indian manatee that was tested using behavioral methods could apparently detect sounds from 15 Hz to 46 kHz (Gerstein et al. 1999). Thus, manatees may hear, or at least detect, sounds in the low-frequency range where most seismic energy is released. It is possible that they are able to feel these low-frequency sounds using vibrotactile receptors or because of resonance in body cavities or bone conduction.

Based on measurements of evoked potentials, manatee hearing is apparently best around 1–1.5 kHz (Bullock et al. 1982). However, behavioral testing suggests their best sensitivity is at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

(c) Characteristics of Airgun Pulses

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. The resulting downward-directed pulse has a duration of only 10 to 20 ms, with only one strong positive and one strong negative peak pressure (Caldwell and Dragoset 2000). Most energy emitted from airguns is at relatively low frequencies. For example, typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain some energy up to 500–1000 Hz and above (Goold and Fish 1998). The pulsed sounds associated with seismic exploration have higher peak levels than other industrial sounds to which whales and other marine mammals are routinely exposed. The only sources with higher or comparable effective source levels are explosions.

The peak-to-peak source level of the 20-gun array to be used during the proposed seismic survey is 262 dB re 1 μPa at 1 m (see Section I, above). This is the nominal source level applicable to downward propagation. The effective source level for horizontal propagation are lower. The only sources with higher or comparable effective source levels than the 20-gun array are explosions and high-power sonars operating near maximum power.

Several important mitigating factors need to be kept in mind. ***(1)*** Airgun arrays produce intermittent sounds, involving emission of a strong sound pulse for a small fraction of a second followed by several seconds of near silence. In contrast, some other sources produce sounds with lower peak levels, but their sounds are continuous or discontinuous but continuing for much longer durations than seismic pulses. ***(2)*** Airgun arrays are designed to transmit strong sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-target areas. ***(3)*** An airgun array is a distributed source, not a point source. The nominal source level is an estimate of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array. That figure is useful in calculating the expected received levels in the far field, i.e., at moderate and long distances. Because the airgun array is not a single point source, there is no one location within the near field (or anywhere else) where the received level is as high as the nominal source level.

The strengths of airgun pulses can be measured in different ways, and it is important to know which method is being used when interpreting quoted source or received levels. Geophysicists usually quote peak-to-peak levels, in bar-meters or dB re 1 μPa·m. The peak (= zero-to-peak) level for the same pulse is typically about 6 dB less. In the biological literature, levels of received airgun pulses are often described based on the "average" or "root-mean-square" (rms) level over the duration of the pulse. The rms value for a given airgun pulse is typically about 10 dB lower than the peak level, and 16 dB lower than the peak-to-peak value (Greene 1997; McCauley et al. 1998, 2000a). A fourth measure that is sometimes used is the energy level, in dB re 1 $\mu Pa^2 \cdot s$. Because the pulses are <1 s in duration, the numerical value of the energy is lower than the rms pressure level, but the units are different. Because the level of a given pulse will differ substantially depending on which of these measures is being applied, it is important to be aware which measure is in use when interpreting any quoted pulse level. In the past, NMFS has commonly referred to rms levels when discussing levels of pulsed sounds that might "harass" marine mammals.

Seismic sound received at any given point will arrive via a direct path, indirect paths that include reflection from the sea surface and bottom, and often indirect paths including segments through the bottom sediments. Sounds propagating via indirect paths travel longer distances and often arrive later than sounds arriving via a direct path. (However, sound traveling in the bottom may travel faster than that in the water, and thus may, in some situations, arrive slightly earlier than the direct arrival despite traveling a greater distance.) These variations in travel time have the effect of lengthening the duration of the received pulse. Near the source, the predominant part of a seismic pulse is about 10 to 20 ms in duration. In comparison, the pulse duration as received at long horizontal distances can be much greater. For example, for one airgun array operating in the Beaufort Sea, pulse duration was about 300 ms at a distance of 8 km (4.3 n.mi.), 500 ms at 20 km (10.8 n.mi.), and 850 ms at 73 km or 39.4 n.mi. (Greene and Richardson 1988).

Another important aspect of sound propagation is that received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995). Paired measurements of received airgun sounds at depths of 3 m (9.8 ft) vs. 9 m (29.5 ft) or 18 m (59 ft) have shown that received levels are typically several decibels lower at 3 m (Greene and Richardson 1988). For a mammal whose auditory organs are within 0.5 or 1 m (1.6–3.3 ft) of the surface, the received level of the predominant low-frequency components of the airgun pulses would be further reduced.

Pulses of underwater sound from open-water seismic exploration are often detected 50–100 km (27–54 n.mi.) from the source location, even during operations in nearshore waters (Greene and Richardson 1988; Burgess and Greene 1999). At those distances, the received levels are low—below 120 dB re 1 μPa on an approximate rms basis. However, faint seismic pulses are sometimes detectable at even greater ranges (e.g., Bowles et al. 1994; Fox et al. 2002). Considerably higher levels can occur at distances out to several kilometers from an operating airgun array.

The distances at which seismic pulses are expected to diminish to various received levels (190, 180, 170 and 160 dB re 1 μPa, on an rms basis) are tabulated, for the 20-gun array in Table 1 (see Section I, above). As previously noted, data from an acoustical calibration study in the Gulf of Mexico will be used to verify or improve these distance estimates prior to the proposed seismic survey. Section I includes additional details concerning expected levels at various distances and angles relative to the airgun array.

(d) Masking Effects of Seismic Surveys

In this and following sections, we discuss what is known about the effects on marine mammals of the types of airgun operations planned by LDEO. The types of effects considered are (1) masking, (2) disturbance, and (3) potential hearing impairment and other physical effects.

Masking effects on marine mammal calls and other natural sounds are expected to be limited. Seismic sounds are short pulses occurring for less than 1 s every 20 s or thereabouts. Sounds from the multibeam sonar are very short pulses, occurring for 1–10 ms once every 1 to 15 s, depending on water depth. (During operations in deep water, the duration of each pulse from the multibeam sonar as received at any one location would actually be only $1/5^{th}$ or at most $2/5^{th}$ of 1-10 ms, given the segmented nature of the pulses—see § I.) Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 Hz. These low frequencies are mainly used by mysticetes, but generally not by odontocetes, pinnipeds, or sirenians. An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the marine mammal signal. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of many marine mammals vs. airgun sounds, communication and echolocation are not expected to be disrupted. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; reviewed in Richardson et al. 1995:233*ff,* 364*ff*). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking.

(e) Disturbance by Seismic Surveys

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Disturbance is one of the main concerns in this project. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause “Level B” harassment of certain marine mammals. Level B harassment is defined as “...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.”

There has been debate regarding how substantial a change in behavior or mammal activity is required before the animal should be deemed to be “taken by Level B harassment”. NMFS has recently stated that

> “…a simple change in a marine mammal’s actions does not always rise to the level of disruption of its behavioral patterns. … If the only reaction to the [human] activity on the part of the marine mammal is within the normal repertoire of actions that are required to carry out that behavioral pattern, NMFS considers [the human] activity not to have caused a disruption of the behavioral pattern, provided the animal’s reaction is not otherwise significant enough to be considered disruptive due to length or severity. Therefore, for example, a short-term change in breathing rates or a

somewhat shortened or lengthened dive sequence that are within the animal's normal range and that do not have any biological significance (i.e., do no disrupt the animal's overall behavioral pattern of breathing under the circumstances), do not rise to a level requiring a small take authorization." (NMFS 2001, p. 9293).

Based on this guidance from NMFS, we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Behavioral reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

Baleen Whales

Humpback, gray, and bowhead whales often reacted to noise pulses from marine seismic exploration by deviating from their normal migration route and/or interrupting their feeding and moving away (e.g. Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999). Fin and blue whales also show some behavioral reactions to airgun noise (McDonald et al. 1995; Stone 2003). Prior to the late 1990s, it was thought that bowhead whales, gray whales, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 μPa rms, but that subtle behavioral changes sometimes become evident at somewhat lower received levels. Recent studies have shown that some species of baleen whales may show strong avoidance at received levels somewhat lower than 160–170 dB re 1 μPa rms. The observed avoidance reactions involved movement away from feeding locations or statistically significant deviations in the whales' direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Humpback Whales.—McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-gun 2678-in^3 array, and to a single 20 in^3 airgun with source level 227 dB re 1 µPa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single gun. Avoidance reactions began at 5–8 km (2.7–4.3 n.mi.) from the array and those reactions kept most pods about 3–4 km (1.6–2.2 n.mi.) from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km (7.6 n.mi.). Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 µPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The standoff range, i.e., the closest point of approach of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of 5–8 km (2.7–4.3 n.mi.) from the airgun array and 2 km (1.1 n.mi.) from the single gun. However, some individual humpback whales, especially males, approached within distances 100–400 m (328–1312 ft), where the maximum received level was 179 dB re 1 µPa rms.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150–169 dB re 1 µPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa on an approximate rms basis.

Bowhead Whales.—Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6 to 99 km (3–53 n.mi.) and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. However, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis. Bowheads usually did show strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km or 1.6–3.8 n.mi.) and when received levels of airgun sounds were 152–178 dB (Richardson et al. 1986, 1995; Ljungblad et al. 1988). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-gun array with a source level of 248 dB at a distance of 7.5 km (4 n.mi.), and swam away when it came within about 2 km (1.1 n.mi.). Some whales continued feeding until the vessel was 3 km (1.6 n.mi.) away. Feeding bowhead whales tend to tolerate higher sound levels than migrating whales before showing an overt change in behavior. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996-98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km (10.8–16.2 n.mi.), and that few bowheads approached within 20 km (10.8 n.mi.). Received sound levels at those distances were only 116–135 dB re 1 µPa (rms). Some whales apparently began to deflect their migration path when still as much as 35 km (19 n.mi.) away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12–24 h after seismic shooting stopped. These and other data suggest that migrating bowhead whales are more responsive to seismic pulses than were summering bowheads.

Gray Whales.—Malme et al. (1986, 1988) studied the responses of feeding gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6 to 2.8 km (1.4–1.5 n.mi.) from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 μPa and higher, on an approximate rms basis. The 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km (1.3 n.mi.) from a 4000-in^3 array operating off central California (CPA = closest point of approach). This would occur at an average received sound level of about 170 dB (rms). Some slight behavioral changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that Western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001. However, there were indications of subtle behavioral effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002).

Rorquals.—Blue, sei, fin, and minke whales have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of about 1.6 km (0.9 n.mi.) from the array during shooting and 1.0 km (0.5 n.mi.) during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

Discussion and Conclusions.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, recent studies of humpback and especially migrating bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the seismic array. (See later subsection "*Numbers… 'Taken by Harassment'*" for discussion of the predicted distances at which whales may exhibit avoidance reactions from the airgun array that will be deployed during the proposed seismic survey.)

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

Toothed Whales

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales, and none similar in size and scope to the studies of humpback, bowhead and gray whales mentioned above. However, systematic work on sperm whales is underway.

Delphinids.—Seismic operators sometimes see species of toothed whales near operating airgun arrays (e.g., Duncan 1985; Arnold 1996; Stone 2003). When a 3959 in^3, 18-gun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel regardless of whether the guns were firing. However, in Puget Sound, Dall's porpoises observed when a 6000 in^3, 12–16 gun array was firing tended to be heading away from the boat (Calambokidis and Osmek 1998).

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180-m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km (0.5 n.mi.) radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km (0.3 n.mi.) or more for most species groups. Killer whales also appear to be more tolerant of seismic shooting in deeper waters.

For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the United Kingdom in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel, etc.) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including white-beaked dolphins, *Lagenorhynchus* spp., and other dolphin spp. showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp., harbor porpoises, and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

Captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and white whale to single impulses from a watergun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited a reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviors were exhibited by captive bottlenose dolphins and a white whale exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviors in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting the aversive behaviors mentioned above.

Observations of odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be relevant as an indicator of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were "not always effective" in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for TTS, the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Beaked Whales.—There are no data on the behavioral reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001). However, those vessels were not emitting airgun pulses.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There has been a recent (Sept. 2002) stranding of Cuvier's beaked whales in the Gulf of California (Mexico) when the *Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002). This might be a first indication[2] that seismic surveys can have effects similar to those attributed to naval sonars. However, the evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

Sperm Whales.—All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km or 162 n.mi.) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in U.K. waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. However, the U.K. results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 µPa pk-pk (Madsen et al. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002; Tyack et al. in press), along with a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys (Mate in press). During two controlled exposure experiments where sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 µPa, there was no indication of avoidance of the vessel or changes in feeding efficiency (Tyack et al. in press). The received sounds were measured on an "rms over octave band with most energy" basis (P. Tyack, pers. comm. to LGL Ltd.); the broadband rms value would be somewhat higher. Although the sample size from the initial work was small (four whales during two experiments), the results are consistent with those off northern Norway.

[2] It is quite unlikely that an earlier stranding of Cuvier's beaked whales in the Galapagos, during April 2000, was asociated with a then-ongoing seismic survey as "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry 2002).

Conclusions.—Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the U.K., show localized avoidance. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown. Most of the proposed seismic survey will be conducted in water <50 m deep that is very unlikely to be occupied by beaked whales. The ramp-ups that are planned at the start of each period of airgun operation are intended to encourage marine mammals to move away before the sound level becomes high. This mitigation measure is planned on the assumption that a short (few hours) period of displacement from the originally-occupied location is preferable to sudden exposure to high sound levels if there was a sudden onset of full-power airgun operations. Also, if beaked whales (or other species) are detected within the designated safety zones, airgun operations will be suspended. Given the shallow water depth, ramp-ups, and monitoring and power-down provisions, effects of the Yucatán project on beaked whales are unlikely, and if they occurred, are most likely to be minor and short term.

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies in recent years. Monitoring studies in the Beaufort Sea during 1996-2001 provide a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Pinnipeds exposed to seismic surveys have also been observed during recent seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of seals exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* G.D. Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the United Kingdom, a radio-telemetry study has demonstrated short-term changes in the behavior of harbor (=common) seals and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioral responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km (1.3 n.mi.) from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioral response, even when the array was within 500 m (1641 ft). All grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behavior modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array." (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998).

Monitoring work in the Alaskan Beaufort Sea during 1996-2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating then when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundreds of meters, and many seals remained within 100–200 m (328–656 ft) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviors, e.g. "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

Manatees

Little information is available on the responses of manatees to industrial noise sources and no information is available on the reactions of manatees to airgun noise. What information there is on manatee reactions to disturbance suggests that sirenians were disturbed by aircraft noise from a low (20-160 m) and slow (<20 km/h) helicopter (Rathbun 1988). However, many manatees exposed to boats and tourists are becoming tame, approaching both boats and people (Curtin and Tyson 1993). In Florida, more manatees are killed by collisions with boats than by any other known causes (O'Shea et al. 1985; Ackerman et al. 1989). Although manatees can apparently hear the sound frequencies emitted by outboard engines (Gerstein et al. 1999), manatees do not appear able to localize the direction from which the boat is traveling. Manatees often attempt to avoid oncoming boats by diving, turning, or swimming away, but their reaction is usually slow and does not begin until the boat is within 50-100 m, increasing the likelihood of collisions (Hartman 1979; Weigle et al. 1993). Although habituation of manatees to vessel travel has occurred in some areas, there is evidence of reduce use of some areas with chronic boat disturbance (Provancha and Provancha 1988). Winter aggregations in favored warm-water habitats can be dispersed by human activity. In Queensland, dugongs in shallow (<2 m) water sometimes swim rapidly in response to motorboats up to 1 km away, often heading for deeper water even if that means swimming toward the vessel (Preen 1992). Dugongs in deeper water are less responsive, often diving several seconds before the boat arrives and resurfacing several seconds after it has passed.

It is unlikely that any manatees will be encountered in the project area, given the lack of recent sightings there and their preference for water shallower than that where the seismic vessel normally operates. Also, in the unlikely event that a manatee is approached by the seismic vessel, the mitigation and monitoring systems in place to protect cetaceans should minimize the likelihood that a manatee would be exposed to sound levels with potential to cause harm.

(f) Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. The minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable Temporary Threshold Shift (TTS). The level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 µPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shutdown) radii planned for the Chicxulub Crater cruise. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. As discussed below, the 180 dB criterion for cetaceans is probably quite conservative (i.e., lower than necessary to avoid auditory injury), at least for delphinids.

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array (and multibeam sonar), and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals.

Toothed Whales.—Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 μPa rms at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss; all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound pressure level) of 221 dB re 1 μPa produced no more than a slight and temporary reduction in hearing.

A similar study was conducted by Finneran et al. (2002) using an 80 in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 μPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value ~4 min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 μPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2000, 2002). In this study, TTS was defined as occurring when there was a 6 dB or larger increase in post-exposure thresholds; the reference to masking (<u>M</u>TTS) refers to the fact that these measurements were obtained under conditions with substantial (but controlled) background noise. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10–13 ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1 s or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With single short pulses, the TTS threshold appears to be (to a first approximation) a function of the energy content of the pulse (Finneran et al. 2002). The degree to which this generalization holds for other types of signals is unclear (Nachtigall et al. 2003). In particular, additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (approx. 221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel.

Baleen Whales.—There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale.

Pinnipeds.—TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. However, two California sea lions did not incur TTS when exposed to single brief pulses with received levels (rms) of ~178 and 183 dB re 1 µPa and total energy fluxes of 161 and 163 dB re 1 µPa^2 · s (Finneran et al. 2003). For sounds of relatively long duration (20–22 min), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100–2000 Hz range. Mild TTS became evident when the received levels were 60–75 dB above the respective hearing thresholds, i.e., at received levels of about 135–150 dB. Three of the five subjects showed shifts of ~4.6–4.9 dB and all recovered to baseline hearing sensitivity within 24 hours of exposure. Schusterman et al. (2000) showed that TTS thresholds of these seals were somewhat lower when the animals were exposed to the sound for 40 min than for 20–22 min, confirming that there is a duration effect in pinnipeds. There are some indications that, for corresponding durations of sound, some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999; Ketten et al. 2001; *cf*. Au et al. 2000).

Likelihood of Incurring TTS.—A marine mammal within a radius of ≤100 m (≤328 ft) around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 µPa (rms). The corresponding limit for pinnipeds has been set at 190 dB. The predicted 180 and 190 dB distances for the 20-airgun array operated by LDEO are summarized in Section I. These sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to seismic pulses stronger than 180 dB re 1 µPa rms.

It has been shown that most large whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which is standard operational protocol for LDEO, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984–1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the initial stages of a ramp-up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience

TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal. However, given the evidence that mammals close to an airgun array might incur TTS, there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*).

Single or occasional occurrences of mild TTS do not cause permanent auditory damage in terrestrial mammals, and presumably do not do so in marine mammals. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002; Nachtigall et al. 2003). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). For impulse sounds with very rapid rise times (e.g., those associated with explosions or gunfire), a received level not greatly in excess of the TTS threshold may start to elicit PTS. Rise times for airgun pulses are rapid, but less rapid than for explosions.

Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals. Some factors that contribute to onset of PTS are as follows:

- exposure to single very intense sound,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1 μPa (pk-pk) in odontocetes, then the PTS threshold might be as high as 240 dB re 1 μPa (pk-pk). In the units used by geophysicists, this is 10 bar-m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and pinnipeds may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Some pinnipeds do not show strong avoidance of operating airguns, but pinnipeds are unlikely to be encountered during the present project.

Although it is unlikely that the planned airgun operations could cause PTS in any marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. The planned monitoring and mitigation measures, including visual monitoring, course alteration, ramp-ups, and power-downs of the airguns when mammals are seen within the "safety radii", and will minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

(g) Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in a recent (2002) case, an LDEO seismic survey, has raised the possibility that beaked whales may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1 μPa, but the -53C briefly operated at an unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or perhaps died at sea (Balcomb and Claridge 2001).

Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24-25 September 2002 in the Canary Islands, where naval maneuvers were taking place.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As discussed earlier, there has been a recent (Sept. 2002) stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a seismic survey by the LDEO/NSF vessel *Ewing* was underway in the general area (Malakoff 2002). The airgun array in use during that project was the *Ewing*'s 20-gun 8490-in^3 array. This might be a first indication that seismic surveys can have effects, at least on beaked whales, similar to the suspected effects of naval sonars. However, the evidence linking the Gulf of California strandings to the seismic surveys is inconclusive, and to this date is not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam bathymetric sonar at the same time but, as discussed below, this sonar had much less potential than the aforementioned naval sonars to affect beaked whales. Although the link between the Gulf of California strandings and the seismic (plus multibeam sonar) survey is inconclusive, this plus the various incidents involving beaked whale strandings "associated with" naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(h) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might occur in marine mammals exposed to strong underwater sound might, in theory, include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays. However, there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods.

Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). However, there is essentially no information about the occurrence of noise-induced stress in marine mammals. Also, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. Diving marine mammals are not subject to the bends or air embolism because, unlike a human SCUBA diver, they only breath air at sea level pressure and have protective adaptations against getting the bends. There may be a possibility that high sound levels could cause bubble formation in the blood of diving mammals that in turn could cause an air embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002). Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. The only available information on acoustically-mediated bubble growth in marine mammals is modeling assuming prolonged exposure to sound.

In summary, very little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

(i) Possible Effects of Mid-Frequency Sonar Signals

A multibeam bathymetric sonar (Atlas Hydrosweep DS-2, 15.5-kHz) will be operated from the source vessel at some times during the planned study. Details about this equipment were provided in Section I. Sounds from the multibeam sonar are very short pulses, occurring for 1–10 ms once every 1 to 15 s, depending on water depth. Most of the energy in the sound pulses emitted by this multibeam sonar is at high frequencies, centered at 15.5 kHz. The beam is narrow (2.67º) in fore-aft extent, and wide (140º) in the cross-track extent. Each ping consists of five successive transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the five segments, i.e. for $1/5^{th}$ or at most $2/5^{th}$ of the 1–10 ms.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the Atlas Hydrosweep, (2) have a longer pulse duration, and (3) are directed close to horizontally (vs. downward for the Hydrosweep). The area of possible influence of the Hydrosweep is much smaller (a narrow band below the source vessel). Marine mammals that encounter the Hydrosweep at close range are unlikely to be subjected to repeated pulses because of the narrow fore-aft width of the beam, and will receive only limited amounts of pulse energy because of the short pulses.

Masking

There is little chance that marine mammal communications will be masked appreciably by the multibeam sonar signals given the low duty cycle of the sonar and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to military and other sonars appear to vary by species and circumstance. Sperm whales reacted to military sonar, apparently from a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins et al. 1985). Other early and generally limited observations were summarized in Richardson et al. (1995, p. 301*ff*). More recently, Rendell and Gordon (1999) recorded vocal behavior of pilot whales during periods of active naval sonar transmission. The sonar signal was made up of several components each lasting 0.17 s and sweeping up from 4 to 5 kHz. The pilot whales were significantly more vocal while the pulse trios were being emitted than during the intervening quiet periods, but did not leave the area even after several hours of exposure to the sonar. Reactions of beaked whales near the Bahamas to mid-frequency naval sonars were summarized earlier. Following extended exposure to pulses from a variety of ships, some individuals beached themselves, and others may have abandoned the area (Balcomb and Claridge 2001; NOAA and USN 2001). Pulse durations from these sonars were much longer than those of the LDEO multibeam sonar, and a given mammal would probably receive many pulses. All of these observations are of very limited relevance to the present situation, because exposures to multibeam pulses are expected to be brief as the vessel passes by, and the individual pulses will be very short.

As noted earlier, captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies similar to those that will be emitted by the multi-beam sonar used by LDEO (Ridgway et al. 1997; Schlundt et al. 2000), and to shorter broadband pulsed signals (Finneran et al. 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt et al. 2000; Finneran et al. 2002). Dolphins exposed to 1-s intense tones exhibited short-term changes in behavior when they received sound levels above 178 to 193 dB re 1 µPa rms. Belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran et al. 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran et al. 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway et al. 1997; Schlundt et al. 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans sometimes avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway et al. (1997) and Schlundt (2000).

We are not aware of any data on the reactions of pinnipeds to sonar sounds at frequencies similar to those of the *Ewing*'s multibeam sonar. However, it is likely that pinnipeds can detect these sounds given their hearing abilities (Kastak and Schusterman 1995, 1998, 1999; see also a review in Richardson et al. 1995). Some harp seals (*Pagophilus groenlandicus*) seemed to alter their swimming patterns (exhibited avoidance) when they were exposed to the beam of an echosounder, nominally operating at 200 kHz (Terhune 1976); that frequency is above the range of effective hearing of seals. However, there was significant energy at lower frequencies that would be audible to a harp seal (Richardson et al. 1995). The behavior of ringed (*Phoca hispida*) and Weddell (*Leptonychotes weddelli*) seals fitted with acoustic pingers, transmitting at 60 to 69 kHz, did not seem to be affected by the sounds from these devices. Mate (1993) described experiments where aperiodic 12–17 kHz sound pulses of varying duration were effective, at source levels of 187 dB, in reducing harbor seal abundance near fish hatcheries (although a few older seals may have habituated and foraged nearby with modified techniques such that they were not seen as frequently). For California sea lions, the same system produced a dramatic initial startle response but was otherwise ineffective. Mate (1993) noted that many marine mammals will react to moving sound sources even if strong stationary sources are tolerated. Mate also noted that, by not using swept frequencies, this experimental acoustic source lost the illusion of motion that would have been simulated by Doppler-like frequency sweeps.

In summary, cetacean behavioral reactions to military and other sonars appear to vary by species and circumstance. While there may be a link between naval sonar use and changes in cetacean vocalization rates and movements, it is unclear what impact these behavioral changes (which are likely to be short-term) might have on the animals.

As noted earlier in § VII (see "*(e) Disturbance by Seismic Surveys*"), NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, very brief exposure of cetaceans to small numbers of signals from the multibeam bathymetric sonar system would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is much concern that sonar noise can cause serious impacts to marine mammals [for discussion see (g) Strandings and Mortality, above]. However, the multibeam sonar proposed for use by LDEO is quite different than sonars used for navy operations. Pulse duration of the multibeam sonar is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the multibeam sonar for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth. (Navy sonars often use near-horizontally-directed sound.) These factors would all reduce the sound energy received from the multibeam sonar rather drastically relative to that from the sonars used by the Navy.

(j) Possible Effects of the Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel at some times during the planned study. Details about this equipment were provided in Section I. Sounds from the sub-bottom profiler are very short pulses, occurring for 1, 2 or 4 ms once every second. Most of the energy in the sound pulses emitted by this multibeam sonar is at mid frequencies, centered at 3.5 kHz. The beamwidth is ~30° and is directed downward.

Sound levels have not been measured directly for the sub-bottom profiler used by the *Ewing*, but Burgess and Lawson (2000) measured the sounds propagating more or less horizontally from a similar unit with similar source output (205 dB re 1 µPa·m). The 160 and 180 dB re 1 µPa (rms) radii, in the horizontal direction, were estimated to be, respectively, near 20 m (66 ft) and 8 m (26 ft) from the source, as measured in 13 m (43 ft) water depth. The corresponding distances for an animal in the beam below the transducer would be greater, on the order of 180 m (591 ft) and 18 m or 59 ft (assuming spherical spreading).

The sub-bottom profiler on the *Ewing* has a stated maximum source level of 204 dB re 1 µPa·m (see § I). Thus the received level would be expected to decrease to 160 and 180 dB about 160 m (525 ft) and 16 m (52 ft) below the transducer, respectively (again assuming spherical spreading). Corresponding distances in the horizontal plane would be lower, given the directionality of this source (30° beamwidth) and the measurements of Burgess and Lawson (2000).

Masking

There is little chance that marine mammal communications will be masked appreciably by the sub-bottom profiler signals given its relatively low power output, the low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to pulsed sound sources are discussed above and responses to the sub-bottom profiler are likely to be similar to those of other pulsed sources at the same received levels. However, the pulsed signals from the sub-bottom profiler are much weaker than those from the airgun array and the multibeam sonar. Therefore, behavioral responses are not expected unless marine mammals were very close to the source, e.g., with about 160 m (525 ft) below the vessel, or a lesser distance to the side.

As noted earlier in § VII (see "*(e) Disturbance by Seismic Surveys*"), NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, very brief exposure of cetaceans to small numbers of signals from the sub-bottom profiler would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Source levels of the sub-bottom profiler are much lower than those of the airguns and the multibeam sonar, which are discussed above. Sound levels from a sub-bottom profiler similar to the one on the *Ewing* were estimated to decrease to 180 dB re 1 µPa (rms) at 8 m (26 ft) horizontally from the source (Burgess and Lawson 2000), and about 18 m downward from the source. Furthermore, received levels of pulsed sounds that are necessary to cause temporary or especially permanent hearing impairment in marine mammals appear to be higher than 180 dB (see earlier). Thus, it is unlikely that the sub-bottom profiler produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position immediately adjacent to the source.

The sub-bottom profiler is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources (or the vessel itself) before the mammals would be close enough to be affected by the less intense sounds from the sub-bottom profiler. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of the higher-power sources (see § XI) would further reduce or eliminate any minor effects of the sub-bottom profiler.

(k) Numbers of Marine Mammals that Might be "Taken by Harassment"

All anticipated takes would be "takes by harassment" as described in §V, involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. In the sections below we describe our methods to estimate "take by harassment" and present our estimates of the numbers that might be affected during the proposed seismic survey off the northern Yucatán Peninsula, based on data on marine mammal abundance in the Gulf of Mexico. This section provides two types of estimates: estimates of the number of potential "takes", and estimates of the number of different individual mammals that might potentially be taken. The distinction is important in this project because the project plan calls for repeated seismic surveys through the same waters. Thus, many of the same individual mammals are likely to be approached by the operating airguns on more than one occasion. This distinction has been recognized in estimating numbers of "takes" during some previous seismic surveys conducted under IHAs (e.g., Moulton and Lawson 2002).

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by operations with the 20-gun array planned to be used for the project. The anticipated radius of influence of the multibeam sonar is less than that for the airgun array (see above). It is assumed that, during simultaneous operations of the multibeam sonar and airguns, any marine mammals close enough to be affected by the sonar would already be affected by the airguns. Therefore, no additional allowance is included for animals that might be affected by the multibeam sonar. Any effects of the multibeam sonar during times when it is operating but the airguns are silent are not considered.

It should be noted that there are few systematic data on the numbers and distributions of marine mammals in the southern Gulf of Mexico and, in particular, in the project area just north of the Yucatán Peninsula (see section IV, above). In the absence of specific data on marine mammal abundance in the planned project area, it has been necessary to base the estimates on a combination of (a) "relative abundance" information from that area and (b) more specific data on abundance in continental shelf waters of the northern Gulf of Mexico. Thus, there is uncertainty about the representativeness of the data and assumptions used below to estimate the potential "take by harassment" there. However, the approach used here seems to be the best available approach. Also, to provide some allowance for these uncertainties, "maximum estimates" as well as the "best estimates" of the numbers potentially affected have been derived.

Basis for Estimating "Take by Harassment" for Chicxulub Crater Cruise

Extensive aircraft- and ship-based surveys have been conducted for marine mammals in the northern Gulf of Mexico (Mullin and Hoggard 2000; Würsig et al. 2000; Baumgartner et al. 2001; Davis et al. 2002). In contrast, little is known about cetacean abundance and distribution in the southern Gulf. Ortega-Ortiz (2002) compiled sighting and stranding data for the southern Gulf and conducted shipboard suveys in that area. However, survey effort within the proposed study area was limited. He noted that bottlenose dolphins comprise most (71%) of the existing cetacean records in the southern Gulf of Mexico, due to the abundance of that species in shallow water where most survey effort has been concentrated (Ortega-Ortiz 2002). However, absolute densities of bottlenose dolphins and other cetaceans in that area are unknown.

Density data are available for cetacean species in the northern Gulf of Mexico, based on the 1996/97 GulfCet II surveys (Mullin and Hoggard 2000) and earlier projects. However, oceanographic and other conditions strongly influence the distribution and numbers of marine mammals present in an area (Davis et al. 2002). Thus, the densities derived from surveys in the northern Gulf of Mexico may not be representative of the densities that will be encountered during the proposed study north of the Yucatán Peninsula. In addition, the majority of the GulfCet II surveys were conducted in the northern oceanic Gulf, where water depths ranged from 200 to 2000 m or 656 to 6562 ft (in contrast to the proposed survey area, where water depths are mainly <50 m or <164 ft).

Therefore, densities from the northern oceanic Gulf of Mexico were not deemed appropriate as a basis to calculate the potential "take by harassment" in the proposed study area north of the Yucatán Peninsula. However, Mullin and Hoggard (2000) gave density estimates for bottlenose dolphins from shipboard surveys over shelf waters (<100 m or <328 ft) in the northern Gulf. We used the density of bottlenose dolphins in shelf waters from Mullin and Hoggard (2000) to calculate an approximate estimate of potential "take by harassment" for that species during the planned project. This calculation assumes that the density of bottlenose dolphins is similar in the planned study area as in continental shelf waters of the northern Gulf of Mexico. This estimate of the number of bottlenose dolphins that might be affected, combined with data on the relative abundances of different delphinid species in the southern Gulf of

Mexico (from Ortega-Ortiz 2002), provided a basis to derive a rough estimate of the potential "take by harassment" for each delphinid species. Ortega-Ortiz (2002) noted that bottlenose dolphins make up ~71% of all cetacean records (generally in shallow waters) in the southern Gulf. Relative abundance values for deep-water species (e.g., sperm whale, dwarf/pygmy sperm whale) were assumed to be near zero, regardless of the actual (low) numbers of records, because these species are unlikely to occur in the proposed study area (depths mainly <50 m). In addition, baleen whales are rare in the Gulf of Mexico and are unlikely to be sighted there.

The density for bottlenose dolphins as derived from the GulfCet surveys was corrected, by the original authors, for detectability bias [$f(0)$], but not for availability bias [$g(0)$]. $g(0)$ is a measure of the probability of detecting an animal that is present on the trackline, and $f(0)$ is a measure of the rate at which sightability diminishes with increasing distance from the trackline. We used the g(0) value from Koski et al. (1998) for bottlenose dolphins in waters off southern California to correct the density further. Both $f(0)$ and $g(0)$ are specific to the survey vessel, the area where the surveys are being conducted, the sea state conditions during the survey, the species or species group, and to the observer(s) who is conducting the survey. Ideally, $f(0)$ and $g(0)$ values from one survey should not be used to "correct" density estimates from a different survey. However, failure to apply some such corrections would result in severe underestimates of the numbers of marine mammals that might be present and potentially affected.

Potential Number of "Takes by Harassment"

To estimate the potential number of occasions when each species might be exposed to received levels levels ≥160 dB re 1 µPa (rms), the corrected density was multiplied by the linear extent of the proposed survey effort (about 3313 km or 1789 n.mi.). This number was then multiplied by cross-track distance within which the received level of pulses from the 20-airgun array is expected to be ≥160 dB re 1 µPa (rms), i.e., 2 x 9.0 km = 18 km. Based on this method, the "best estimate" of the number of bottlenose dolphin exposures to seismic sounds ≥160 dB re 1 µPa (rms) was obtained (9107 exposures; Table 7). The "best estimates" for other species were then derived from the bottlenose dolphin figure based on the relative abundance from Ortega-Ortiz (2002). For example, Atlantic spotted dolphins accounted for 7.7 % of the records, vs. 71 % for bottlenose dolphins. Thus, for Atlantic spotted dolphins, the best estimate of the total number of exposures is 9107 ×7.7 / 71 = 988.

The "best estimates" show that no endangered marine mammals are expected to be "taken by harassment". The "best estimates" of the number of exposures of bottlenose, Atlantic spotted, and pantropical spotted dolphins are 9107, 988, and 436, respectively. Best estimates for other species are lower (Table 7).

The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive and delphinids generally appear to be more tolerant of strong low-frequency sounds than are most baleen whales. Delphinids commonly occur within distances where received levels would be expected to exceed 160 dB (rms). There is no agreement regarding any alternative "take" criterion for dolphins exposed to airgun sounds. However, if only those dolphins exposed to ≥170 dB re 1 µPa (rms) were, on average, affected sufficiently to be considered "taken by harassment", then the best estimates of the numbers of exposures for the three most common species would be 2631, 285, and 126, respectively. These values are based on the predicted 170 dB radii around the 20-airgun array (2600 m or 8530 ft) and are considered to be more realistic estimates of the numbers of occasions when each species of delphinid may be affected.

TABLE 7. Estimated numbers of marine mammals that might be exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) during LDEO's seismic survey with a 20-gun array north of the Yucatán Peninsula in the Gulf of Mexico in March–April 2004. For Delphinidae, estimated numbers of exposures to sounds ≥170 dB are also shown in parentheses (see text). Species shown in italics are listed as endangered under the U.S. ESA. Because much of the project area will be surveyed several times, many mammals will be exposed to 160 or 170 dB on more than one occasion. Thus, the number of different individuals exposed to such levels, estimated in the two rightmost columns, may be substantially less than the number of exposures (see text).

Species	"Best Estimate" of the Number of Exposures to Sound Levels ≥160 dB (≥170 dB)		% of North Atlantic Population	"Maximum Estimate" of the Number of Exposures to Sound Levels ≥160 dB (≥170 dB)		Requested Authorization		
						Number of Exposures to ≥160 dB	Individuals Exposed to ≥160 dB (≥170 dB)	
Physeteridae								
Sperm whale	*0*		*0*	0		*10*	*10*	
Dwarf/Pygmy sperm whale	0		0	0		10	10	
Ziphiidae								
Cuvier's beaked whale	0		0	0		10	10	
Sowerby's beaked whale	0		0	0		10	10	
Gervais' beaked whale	0		0	0		10	10	
Blainville's beaked whale	0		0	0		10	10	
Delphinidae								
Rough-toothed dolphin	295	(85)	N.A.	443	(128)	443	274	(87)
Bottlenose dolphin	9107	(2631)	N.A.	13,660	(3946)	13,660	8442	(2679)
Pantropical spotted dolphin	436	(126)	<0.7	654	(189)	654	404	(128)
Atlantic spotted dolphin	988	(285)	<1.8	1481	(428)	1481	915	(291)
Spinner dolphin	26	(7)	<0.2[a]	38	(11)	100	100	
Clymene dolphin	0		0	0		100	100	
Striped dolphin	0		0	0		100	100	
Short-beaked common dolphin						5	5	
Long-beaked common dolphin						5	5	
Fraser's dolphin	6	(1)	N.A.	10	(2)	100	100	
Risso's dolphin	6	(1)	0	10	(2)	10	10	
Melon-headed whale	6	(1)	0.1[a]	10	(2)	100	100	
Pygmy killer whale	0		0	0		15	15	
False killer whale	359	(104)	N.A.	539	(156)	539	333	(106)
Killer whale	6	(1)	0.1	10	(2)	10	10	
Short-finned pilot whale	205	(59)	0	308	(89)	308	190	(60)
Long-finned pilot whale						5	5	
Mysticetes								
North Atlantic right whale	*0*		*0*	*0*		*2*	*2*	
Humpback whale	*0*		*0*	*0*		*2*	*2*	
Minke whale	0		*0*	0		2	2	
Bryde's whale	0		0	0		5	5	
Sei whale	*0*		*0*	*0*		*2*	*2*	
Fin whale	*0*		*0*	*0*		*2*	*2*	
Blue whale	*0*		*0*	*0*		*2*	*2*	
Pinniped								
Hooded seal	0		0	0		5	5	

[a] % of Gulf of Mexico population. N.A. = not available.

To derive a ***"maximum estimate"*** for the number of occasions when cetaceans of each species might be exposed to sound levels ≥160 dB re 1 µPa (rms) during the proposed survey, we used 1.5 times the "best estimate." These values are intended to allow, at least in part, for uncertainty in the assumptions and procedures used in the calculations. Likewise, for delphinids, maximum estimates were also calculated based on the more realistic ≥170 dB assumption (Table 7).

The third-from-the-right column in Table 7 indicates the maximum number of separate "takes" of each species that might occur, based on the 160 dB criterion plus some further upward adjustments. For the less common species, the calculated maximum estimates have been scaled upward to allow for the unlikely possibility of a sighting near the airguns of a group of typical group size. However, some of these uncommon species probably will not be encountered. For most if not all species, the number of occasions with biologically significant disturbance is expected to be lower than allowed for in the third-from-right column of Table 7.

Pinnipeds are not expected to be encountered in the study area north of the Yucatán Peninsula and so the "best estimate" of the number of occasions when pinnipeds might be affected is 0. Although it is unlikely that any pinnipeds will be encountered, we request authorization to "take" pinnipeds (most likely hooded seals) by harassment on as many as 5 occasions, in case they are encountered during the proposed survey.

Manatees are not the subject of this IHA Application to NMFS, since they are managed (in the U.S.A.) by the Fish & Wildlife Service. Nonetheless, it is unlikely that manatees would be taken by harassment, since the occurrence of manatees is considered rare in the proposed study area. There have been no reported live sightings of manatees in the proposed study area since at least 1994 (Morales-Vela et al. 2003).

Potential Number of Different Individuals That Might be "Taken"

The preceding text estimates the number of potential "takes", whereas the following estimates the number of different individual mammals that might potentially be taken. As noted earlier, the distinction is important in this project because there will be repeated seismic surveys through the same waters. Much of the area will be surveyed via both north–south lines and east–west lines. Also, many of the lines will be sufficiently close together such that the 160-dB distance around one line will strongly overlap the corresponding distance around adjacent lines. Thus, many of the same individual mammals are likely to be approached by the operating airguns on more than one occasion, and to come within the 160 dB distance, and perhaps the smaller 170 dB distance, more than once. This means that many of the mammals in the project area may be disturbed more than once. On the other hand, it means that the total number of individuals likely to be disturbed is considerably lower than that calculated above.

The number of different individuals likely to be exposed to 160 dB or 170 dB re 1 µPa (rms) on one or more occasions can be estimated by considering the total marine area that would be within the 160 or 170 dB radii around the operating airguns on at least one occasion. This has been determined by entering the planned survey lines into a Geographic Information System (MapInfo) and using the GIS to determine the relevant areas. The total marine area that would be within the 160 dB distance at some point during the project would be about 14,071 km^2. The corresponding figure based simply on the length of the planned surveys (3313 km) and the 160 dB radius (9 km) was 59,634 km^2, i.e. 3313 × 9 × 2. (The "×2" takes account of the fact that the ≥160 dB zone extends out to 9 km on either side of the survey line.) Of that 59,634 km^2, about 76.4 % (45,563 km^2) would represent areas that come within the 9 km radius for the 2nd, 3rd, 4th, etc., time. Thus, the number of different individuals that might be exposed to

160 dB on one or more occasions would be about 23.6 % (14,071 / 59,634) of the total number of individual exposures if there were no turnover in the mammals occurring within the study area during the project.

Based on the 170 dB criterion, the corresponding figures are as follows: total area within 2.6 km of survey lines, 6170 km^2; area as calculated from total length of surveys, 17,228 km^2 (3313 × 2.6 × 2); former as percent of latter, 35.8 %.

To estimate the number of different mammals of each species that might be exposed to airgun sounds with received levels ≥160 or 170 dB dB re 1 μPa, one might apply the 23.6 % or 35.8 % values to the "Best Estimate", "Maximum Estimate" and "Requested Authorization/Number of Exposures" columns in Table 7. This would only be appropriate for the common species of delphinids, as the estimates for other types of mammals are not based directly on density data. Also, for the common delphinids, it is possible that the resulting figures might be too low because of the movements of animals. There are no data with which to estimate how much effect the animal movements might have on the total number of different individuals exposed to received levels of 160 dB or 170 dB on one or more occasions. As a first approximation, we assume that the number of different individuals that might be exposed would be midway between the estimated number of exposures and the (smaller) number, based on the 23.6 % (for 160 dB) or 35.8 % (for 170 dB) figures, that would apply in the absence of animal movements.

The resultant values for the common species of delphinids are 61.8 % of the 160 dB exposure figures, i.e., (23.6+100)/2, and 67.9 % of the 170 dB figures, i.e., (35.8+100)/2. Thus, the ***best estimates*** are that about 5628, 611, and 269 different bottlenose, Atlantic spotted, and pantropical spotted dolphins, respectively (apparently, the most abundant delphinids in the proposed survey area) might be exposed to seismic sounds ≥160 dB re 1 μPa. These values are 61.8% of the corresponding "best estimates" in the "number of exposures" column of Table 7.

The rightmost two columns of Table 7 show the corresponding ***maximum estimates*** of the numbers of different individuals of each species that might be exposed to airgun sounds with received levels ≥160 or 170 dB re 1 μPa (rms) on one or more occasions during the planned project, incorporating the ×1.5 allowance for uncertainty. The 160 dB figures for the three most common delphinids become 8442, 915, and 404, respectively (Table 7). For species other than six most common delphinids, we make the precautionary assumption that each exposure might involve a different individual, and we make no further specific allowance for lower numbers exposed to ≥170 dB re 1 μPa (rms) than to ≥160 dB.

Conclusions re Effects on Cetaceans

The proposed survey will use a towed airgun array to introduce sound to the ocean floor and a hydrophone streamer and/or OBSs to receive reflected and/or refracted energy. The proposed airgun array is larger than those used in many seismic projects — 20 airguns totaling 8575 in^3. Routine vessel operations other than the proposed seismic survey are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

Strong avoidance reactions by several species of mysticetes to seismic vessels have been observed at ranges up to 6–8 km (3.2–4.3 n.mi.) and occasionally as far as 20–30 km (10.8–16.2 n.mi.) from the source vessel. Some bowhead whales are known to avoid waters within 30 km (16.2 n.mi.) of the seismic operation. However, reactions at such long distances appear to be atypical of other species of mysticetes, and even for bowheads, such behavior may only apply during migration. Furthermore, mysticetes are unlikely to be encountered during the planned study off the northern Yucatán Peninsula, and if they are encountered, the numbers are expected to be low.

Odontocete reactions to seismic pulses, or at least the reactions of dolphins, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, dolphins as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking account of the mitigation measures that are planned, effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". In the cases of mysticetes and sperm whales, these reactions are expected to involve no more than very small numbers of individual cetaceans. Our "best estimate" is that no endangered species will be exposed to sound levels ≥160 dB re 1 µPa (rms) (Table 7). If any endangered cetaceans are exposed to ≥160 dB, the numbers will be small. This potential "take by harassment" will have negligible impact on the individual species and no impact on their populations.

Larger numbers of odontocetes may be affected by the proposed survey, but the population sizes of the few species likely to occur in the operating area are large and the numbers potentially affected are small relative to the population sizes. It is most likely that about 5628, 611, and 269 different bottlenose, Atlantic spotted, and pantropical spotted dolphins, respectively (apparently, the most abundant delphinids in the proposed survey area) might be exposed to seismic sounds ≥160 dB re 1 µPa, measured on an rms basis over the duration of each pulse (Table 7). For other odonocetes, numbers exposed to ≥160 dB will be smaller. For the dolphin species, surveys have not been conducted of most of their range in the North Atlantic Ocean and adjacent waters. Thus, the population sizes shown in Table 6 are based on a small fraction of their respective ranges. Their actual population sizes are presumably much larger than shown in Table 6, and thus the percentages of the populations exposed to ≥160 dB will be smaller than estimated. Totals of about 1786, 194, and 86 different bottlenose, Atlantic spotted, and pantropical spotted dolphins, respectively, and lesser numbers of other delphinid species, might be exposed to ≥170 dB (Table 7). The values based on the ≥170 dB criterion are believed to be a more accurate estimate of the numbers of delphinids potentially affected.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, course alternation, look-outs, non-pursuit, ramp-ups, and power-downs when marine mammals are seen within defined ranges should further reduce short-term reactions to disturbance, and minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequences.

Conclusions re Effects on Pinnipeds

It is most likely that no pinnipeds will be encountered during the proposed seismic survey north of the Yucatán Peninsula, Gulf of Mexico. It is estimated that, as a maximum, 5 pinnipeds may be affected by the proposed survey. If pinnipeds are encountered, they will be extralimital individuals. The proposed seismic survey would have, at most, a short-term effect on their behavior and no long-term impacts on individual pinnipeds or their populations. Responses of pinnipeds to acoustic disturbance are variable, but usually quite limited. Effects are expected to be limited to short-term and localized behavioral changes falling within the MMPA definition of "Level B harassment".

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

There is no legal subsistence hunting for marine mammals in the Gulf of Mexico, and so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

During the period of the proposed survey, marine mammals will be dispersed throughout the proposed study area north of the Yucatán Peninsula. Although no detailed studies of marine mammal occurrence in the study area have been done, no concentrations of marine mammals or marine mammal prey species are known to occur in the study area at the time of year (March and April) when the proposed seismic survey will be conducted.

The proposed airgun operations will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in Sections VI/VII, above.

The actual area contacted temporarily by the OBS receivers will be an insignificant and very small fraction of the marine mammal habitat and the habitat of their food species in the area. The use of OBSs could result in some short-term disturbance to sediments and benthic organisms, but the area that might be disturbed is a very small fraction of the overall area.

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that they (unlike the explosives used in the distant past) do not result in any appreciable fish kill. Various experimental studies showed that airgun discharges cause little or no fish kill, and that any injurious effects were generally limited to the water within a meter or so of an airgun. However, it has recently been found that injurious effects on captive fish, especially on fish hearing, may occur to somewhat greater distances than previously thought (McCauley et al. 2000a,b, 2002; 2003). Even so, any injurious effects on fish would be limited to short distances. Also, many of the fish that might otherwise be within the injury-radius are likely to be displaced from this region prior to the approach of the airguns through avoidance reactions to the passing seismic vessel or to the airgun sounds as received at distances beyond the injury radius.

Short, sharp sounds can cause overt or subtle changes in fish behavior. Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the field to an airgun. When the airgun was discharged, the fish dove from 25 to 55 m (80–180 ft) depth and formed a compact layer. By the end of an hour of exposure to the sound pulses, the fish had habituated; they rose in the water despite the continued presence of the sound pulses. However, they began to descend again when the airgun resumed firing after it had stopped. The whiting dove when received sound levels were higher than 178 dB re 1 μPa (peak pressure[3]) (Pearson et al. 1992).

Pearson et al. (1992) conducted a controlled experiment to determine effects of strong noise pulses on several species of rockfish off the California coast. They used an airgun with a source level of 223 dB re 1 μPa. They noted

- startle responses at received levels of 200–205 dB re 1 μPa (peak pressure) and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- alarm responses at 177–180 dB (peak) for the two sensitive species, and at 186 to 199 dB for other species;
- an overall threshold for the above behavioral response at about 180 dB (peak pressure);
- an extrapolated threshold of about 161 dB (peak) for subtle changes in the behavior of rockfish; and
- a return to pre-exposure behaviors within the 20–60 min exposure period.

In other airgun experiments, catch per unit effort (CPUE) of demersal fish declined when airgun pulses were emitted (Dalen and Raknes 1985; Dalen and Knutsen 1986; Skalski et al. 1992). Reductions in the catch may have resulted from a change in behavior of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish may have changed their swimming and schooling behavior. Fish behavior returned to normal minutes after the sounds ceased. In the Barents Sea abundance of cod and haddock measured acoustically was reduced by 44% within 9.2 km (5.0 n.mi.) of an area where airguns operated (Engås et al. 1993). Actual catches declined by 50% throughout the trial area and 70% within the shooting area. This reduction in catch decreased with increasing distance to 30–33 km (16.2–17.8 n.mi.) where catches were unchanged.

Other recent work concerning behavioral reactions of fish to seismic surveys, and concerning effects of seismic surveys on fishing success, is reviewed in Turnpenny and Nedwell (1994), Santulli et al. (1999), Hirst and Rodhouse (2000), Thomson et al. (2001), Wardle et al. (2001), and Engås and Løkkeborg (2002).

In summary, fish often react to sounds, especially strong and/or intermittent sounds of low frequency. Sound pulses at received levels of 160 dB re 1 μPa (peak) may cause subtle changes in behavior. Pulses at levels of 180 dB (peak) may cause noticeable changes in behavior (Chapman and Hawkins 1969; Pearson et al. 1992; Skalski et al. 1992). It also appears that fish often habituate to repeated strong sounds rather rapidly, on time scales of minutes to an hour. However, the habituation does not endure, and resumption of the disturbing activity may again elicit disturbance responses from the same fish.

Fish near the airguns are likely to dive or exhibit some other kind of behavioral response. This might have short-term impacts on the ability of cetaceans to feed near the survey area. However, only a small fraction of the available habitat would be ensonified at any given time and fish species would return to their pre-disturbance behavior once the seismic activity ceased. Thus the proposed surveys would have

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[3] For airgun pulses, root-mean-square (rms) pressures, averaged over the pulse duration, are on the order of 10-13 dB less than peak pressure (Greene 1997; McCauley et al. 1998, 2000b).

little impact on the abilities of marine mammals to feed in the area where seismic work is planned. Some of the fish that do not avoid the approaching airguns (probably a small number) may be subject to auditory or other injuries.

Zooplankters that are very close to the source may react to the shock wave. These animals have an exoskeleton and no air sacs. Little or no mortality is expected. Many crustaceans can make sounds and some crustacea and other invertebrates have some type of sound receptor. However, the reactions of zooplankters to sound are not known. Some mysticetes feed on concentrations of zooplankton. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause this type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and this would translate into negligible impacts on feeding mysticetes. In the present project area, mysticetes are expected to be rare.

Because of the reasons noted above, the operations are not expected to cause significant impacts on habitats used by marine mammals, or on the food sources that marine mammals utilize.

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The effects of the planned activity on marine mammal habitats and food resources are expected to be negligible, as described above. A small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity. However, the proposed study area north of the Yucatán Peninsula is not known to be a critical feeding or calving area for any of the species that are found there. Therefore, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations.

XI. Mitigation Measures

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

For the Chicxulub survey, LDEO will use a 20-gun array. The airguns comprising the array will be spread out horizontally, so that the energy will be directed mostly downward. The directional nature of the array to be used in this project is an important mitigating factor. This directionality will result in reduced sound levels at any given horizontal distance than would be expected at that distance if the source were omnidirectional with the stated nominal source level.

The sound pressure fields have been modeled by LDEO in relation to distance and direction from the 20-gun array (Fig. 3). The radii around the 20-gun array where the received levels would be 180 dB and 190 dB re 1 μPa (rms) were estimated as 900 m (2953 ft) and 275 m (902 ft), respectively. The 180 and 190 dB shutdown criteria, applicable to cetaceans and pinnipeds, respectively, are specified by NMFS (2000).

These radii are expected to be verified or refined prior to the seismic survey, using data collected during the aforementioned acoustical measurement study in shallow water within the northern Gulf of Mexico (see separate IHA application, EA, and 90-day report).

Vessel-based observers will watch for marine mammals near the array when it is in use. LDEO proposes to power-down the airguns if marine mammals are detected within the proposed safety radii. A power-down involves decreasing the number of airguns in use such that the radius of the 180-dB zone is decreased to the extent that marine mammals are not in the safety zone. A power-down may also occur when the vessel is moving from one seismic line to another. (However, during parts of this project, it is planned to operate the full airgun array during line changes—see § I.) During a power-down, one airgun will be operated. The continued operation of one airgun will alert marine mammals to the presence of the seismic vessel in the area. In contrast, a shut-down occurs when all airgun activity is suspended due to ship operations (e.g., survey is complete, repair of airguns is required, etc.).

Also, LDEO proposes to use a ramp-up procedure when commencing operations using the 20-gun array. Ramp-up will begin with the smallest gun in the array (80 in^3). Guns will be added in a sequence such that the source level of the array will increase at a rate no greater than 6 dB per 5-min period over a total duration of ~25 min. Throughout the ramp-up procedures, the safety zone as defined for the full 20-gun array will be maintained.

To minimize the likelihood that impacts will occur to the species, stocks, and subsistence use, the airgun operations will be conducted in accordance with all U.S. federal and local regulations. LDEO will coordinate all activities with the relevant federal and state agencies (particularly the National Marine Fisheries Service) and Mexican authorities. The proposed activity will take place in the Mexican EEZ .

The number of individual animals expected to be closely approached during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring, ramp-up, and power-down provisions (see below), effects on those individuals are expected to be limited to behavioral disturbance. This is expected to have negligible impacts on the species and stocks.

We are not aware of any rookeries, mating grounds, areas of concentrated feeding, or other areas of special significance for marine mammals within the planned area of operations during the season of operations.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity.

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime airgun operations and during any nighttime start-ups of the airguns. Airgun operations will be suspended when marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects. During daylight, vessel-based observers will watch for marine mammals near the seismic vessel during periods with shooting (including ramp-ups), and for 30 min prior to the planned start of airgun operations after an extended shut-down. Observers will not be on duty during ongoing seismic operations at night; at night, bridge personnel will watch for marine mammals (insofar as practical at night) and will call for the airguns to be powered-down if marine mammals are observed in or about to enter the safety radii. If the airguns are ramped-up at night, two marine mammal observers will monitor marine mammals near the source vessel for 30 min prior to ramp-up using night vision devices as described below in § XIII.

The proposed monitoring plan is summarized in § XIII.

Proposed Safety Radii

Received sound levels have been modeled for the 20-gun array (Fig. 3 in § I). Based on the modeling, estimates of the 190, 180, 170, and 160 dB re 1 μPa (rms) distances for the 20-gun array are shown in Table 1 (in § I). The radius around the array where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans, was estimated as 900 m (2953 ft). The radius around the array where the received level would be 190 dB re 1 μPa (rms), the safety criterion applicable to pinnipeds, was estimated as 275 m (902 ft). The radii will be verified prior to the cruise using data from the acoustic verification study that was conducted by LDEO in shallow waters within the northern Gulf of Mexico from 27 May to 2 June 2003. Conservative (larger) safety radii (1.5 times the modeled radii) would be used as shutdown distances in the unexpected event that the modeled radii have not been verified at the time of the proposed project.

Airguns will be powered-down immediately when cetaceans or pinnipeds are detected within or about to enter the appropriate 180-dB (rms) or 190-dB (rms) radius, respectively. The 180 and 190 dB criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS. LDEO is aware that NMFS is likely to release new noise-exposure guidelines soon. LDEO will be prepared to revise its procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required by the new guidelines.

Mitigation During Operations

The following mitigation measures, as well as marine mammal monitoring, will be adopted during the proposed seismic program, provided that doing so will not compromise operational safety requirements:

1. Speed or course alteration;
2. Power-down procedures;
3. Shut-down procedures; and
4. Ramp-up procedures.

Speed or Course Alteration

If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course will be changed in a manner that also minimizes the effect to the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or power-down of the airguns.

Power-down Procedures

If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's speed and/or course cannot be changed to avoid having the mammal enter the safety radius, the airguns will be powered-down before the mammal is within the safety radius. Likewise, if a mammal is already within the safety zone when first detected, the airguns will be powered-down immediately. During a power-down of the 20-gun array, at least one airgun (80 in^3) normally will be operated, unless a marine mammal is detected within or near the smaller safety radius around that smaller source (see next subsection).

Airgun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it is visually observed to have left the safety zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales).

Shut-down Procedures

If a marine mammal is detected close to the airgun array during a power-down, modeled safety radii for the then-operating source (typically a single gun of 80 in^3) will be maintained. Since no calibration measurements have been done to confirm the modeled safety radii for this single gun, conservative radii will be used (1.5 times the modeled safety radius). For an 80 in^3 airgun, the 180-dB safety radius for cetaceans is 36 m or 118 ft, and the x1.5 conservative radius is 54 m or 177 ft. The corresponding 190-dB radius applicable to pinnipeds is 13 m or 43 ft, with the x1.5 conservative radius being 20 m or 66 ft. If a marine mammal is detected within the appropriate safety radius around the small source in use during a power-down, airgun operations will be entirely shut-down.

Airgun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it is visually observed to have left the safety zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales).

Ramp-up Procedures

A “ramp-up” procedure will be followed when the airgun array begins operating after a specified-duration period without airgun operations. The specified period varies depending on the speed of the source vessel and the size of the airgun array that is being used. Under normal operational conditions (vessel speed 4 knots or 7.4 km/h), the *Ewing* would travel 900 m (2953 ft) in ~7 min. The 900 m distance is the calculated 180 dB safety radius for the 8575 in^3 20 airgun array. Thus a ramp-up would be required after a power-down or shut-down period lasting ~7 min or longer if the *Ewing* was traveling at 4 knots and was towing the 8575 in^3 20 airgun array. If the towing speed is reduced to 3 knots (5.6 km/h) or less, as sometimes required when maneuvering in shallow water, it is proposed that a ramp-up would be required after a “no shooting” period lasting >10 min. At towing speeds not exceeding 3 knots, the source vessel would travel no more than 900 m (2953 ft) in ~10 min. Based on similar calculations, a ramp-up procedure would be required after ~6 min if the speed of the source vessel was 5 knots (9.3 km/h). During programs when a smaller airgun array is being used, the specified period would be based on similar calculations using the time taken for the source vessel to travel to the boundary of the 180 dB safety radius for that array.

Ramp-up will begin with the smallest gun in the 20-gun array (80 in^3). Guns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~25 min. During the ramp-up procedures, the safety zone for the full gun array will be maintained.

If the complete safety radius has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp-up will not commence unless at least one airgun with an SPL of at least 180 dB re 1 μPa (rms) has been operating during the interruption of seismic survey operations. Therefore, it is likely that the 20-gun array will not be ramped up from a complete shut-down at night or in thick fog, since the outer part of the safety zone for this array will not be visible during those conditions. Presently available night vision devices are not effective in detecting marine mammals at distances approaching 900 m. If one airgun has operated during a "power-down" period, ramp-up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away if they choose. Ramp-up of the airguns will not be initiated if a sea turtle is sighted close to the vessel.

XII. PLAN OF COOPERATION

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;

(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;

(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and

(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

The proposed activity will take place in the Gulf of Mexico, north of the Yucatán Peninsula, and no activities will take place in or near a traditional Arctic subsistence hunting area. Therefore, there is no need to contact subsistence communities or to develop a plan of cooperation.

XIII. MONITORING AND REPORTING PLAN

> The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding...

LDEO proposes to sponsor marine mammal monitoring of its seismic program, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated requirements of the Incidental Harassment Authorization.

LDEO's proposed Monitoring Plan is described below. LDEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. LDEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

At least two observers dedicated to marine mammal observations will be stationed aboard LDEO's seismic survey vessel for the seismic survey off the northern Yucatán Peninsula. It is proposed that one or two marine mammal observers (MMOs) aboard the seismic vessel will search for and observe marine mammals whenever airgun operations are in progress during daylight hours. If feasible, observations will also be made during daytime periods without airgun operations.

Two observers will be on duty for 30 min prior to the start of airgun operations after an extended shut-down and during ramp-ups. The 30-min observation period is only required prior to commencing seismic survey operations following a shut-down of the 20-gun array for more than 1 hr. This period is based on the time that it would take a seismic vessel to reach the 160-dB safety radius while operating the array. After 30 min of observation, the ramp-up procedure will be followed.

If ramp-up procedures must be performed at night, two observers will be on duty starting at least 30 min prior to the start of airgun operations and continuing during the subsequent ramp-up procedures. Ramp-up procedures will not commence at night or during the day in poor visibility unless at least one airgun has been operating during the preceding interruption of seismic survey operations. Other than the specified periods mentioned above, no observers will be required to be on duty during seismic operations at night. However, LDEO bridge personnel (port and starboard seamen and one mate) will assist in marine mammal observations whenever possible, and especially during operations at night, when designated marine mammal observers will not normally be on duty. At least one marine mammal observer will be on "standby" at night, in case bridge personnel see a marine mammal. Image-intensifier night-vision devices (NVDs) will be available for use at night.

If the airguns are powered-down, observers will continue to maintain watch to determine when the animal is outside the safety radius. After the observer has determined that the animal has cleared the safety zone [i.e., if it is visually observed to have left the safety zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales], ramp-up of the airguns will occur.

The observer(s) will watch for marine mammals from the highest practical vantagepoint on the vessel, which is either the bridge or the flying bridge. On the bridge of the *Ewing*, the observer's eye level will be 11 m (36 ft) above sea level, allowing for good visibility within a 210º arc. If observers are stationed on the flying bridge, the eye level will be 14.4 m (47.2 ft) above sea level. The observer(s) will systematically scan the area around the vessel with reticle binoculars (e.g., 7 × 50 Fujinon) and with the naked eye during the daytime. At night, night vision equipment will be available (ITT F500 Series Generation 3 binocular image intensifier or equivalent), if required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. (These are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to marine mammals directly.) If a marine mammal is seen well outside the safety radius, the vessel may be maneuvered to avoid having the mammal come within the safety radius (see Section XI, "Mitigation", above). When mammals are detected within or about to enter the designated safety radii, the airguns will be powered down immediately. The observer(s) will continue to maintain watch to determine when the animal is outside the safety radius. Airgun operations will not resume until the animal is observed to be outside the safety radius or until the specified intervals (15 or 30 min) have passed without a re-sighting.

The vessel-based monitoring will provide data required to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions, and thus to estimate the numbers of mammals potentially "taken" by harassment. It will also provide the information needed in order to shut down the airguns at times when mammals are present in or near the safety zone. When a mammal sighting is made, the following information about the sighting will be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to seismic vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.
2. Time, location, heading, speed, activity of the vessel (shooting or not), sea state, visibility, cloud cover, and sun glare.

The data listed under (2) will also be recorded at the start and end of each observation watch and during a watch, whenever there is a change in one or more of the variables.

All mammal observations and airgun shutdowns will be recorded in a standardized format. Data will be entered into a custom database using a laptop computer when observers are off-duty. The accuracy of the data entry will be verified by computerized validity data checks as the data are entered and by subsequent manual checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical or other programs for further processing and archiving.

During seismic operations north of the Yucatán Peninsula, at least two observers will be based aboard the vessel. At least one experienced marine mammal observer (with a minimum of one previous year of marine mammal observation experience) will be on duty aboard the seismic vessel. Observers will be appointed by LDEO with NMFS concurrence.

Observers will be on duty in shifts of duration no longer than 4 hours. The second observer will also be on watch part of the time, including the 30 min periods preceding startup of the airguns and during ramp-ups. Use of two simultaneous observers will increase the proportion of the marine mammals present near the source vessel that are detected. Bridge personnel additional to the dedicated marine mammal observers will also assist in detecting marine mammals and implementing mitigation requirements, and before the start of the seismic survey will be given instruction in how to do so.

Results from the vessel-based observations will provide

1. The basis for real-time mitigation (airgun power-down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

Reporting

A report will be submitted to NMFS within 90 days after the end of the cruise. The end of the Chicxulub Crater cruise is predicted to occur ~4 April 2004. The report will describe the operations that were conducted and the marine mammals that were detected near the operations. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report will summarize the dates and locations of seismic operations, marine mammal sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential "take" of marine mammals by harassment or in other ways.

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

Lamont-Doherty Earth Observatory will coordinate the planned marine mammal monitoring program associated with the seismic survey north of the Yucatán Peninsula, Gulf of Mexico (as summarized in § XIII), with other parties that may have interest in this area and/or be conducting marine mammal studies in the same region during operations.

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